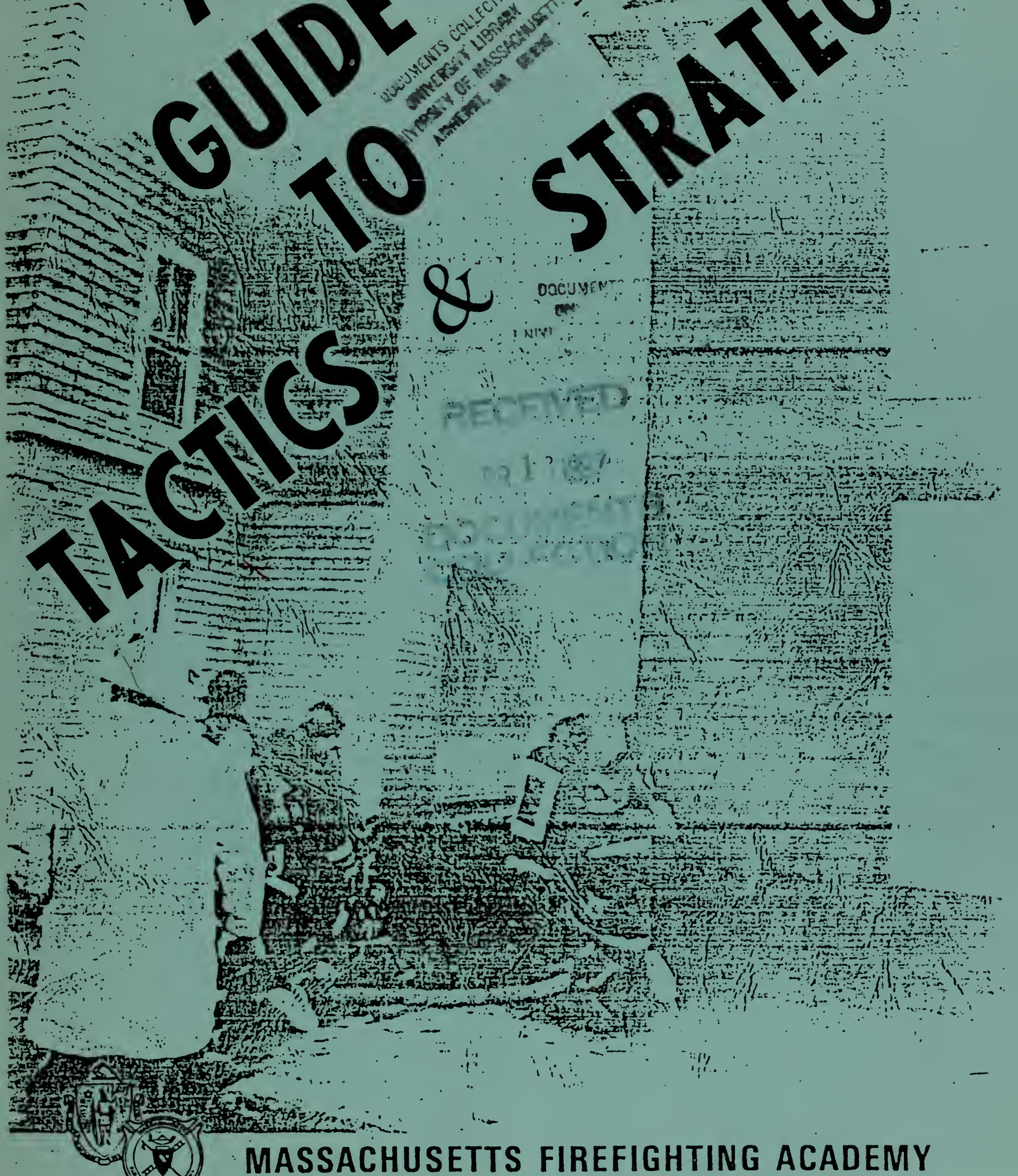
A GUIDE TO TACTICS & STRATEGY



MASSACHUSETTS FIREFIGHTING ACADEMY

CONTENTS

This manual is dedicated to those members of the fire service who have in the past, and will in the future, continue to devote endless hours of study and self-improvement for the professionalism of the service. It is with the hope that their continued unselfish efforts will contribute to the safety of firefighters, as well as a reduction of life and property loss from fire in the Commonwealth that this manual is written and distributed.

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Bibliography

Managing Fire Services, Published for the International City Management Association

Water for Firefighting, by Keith Royer, Iowa State University

Management of Fire Service Operations, by Ronny Coleman

Interior Firefighting, by Lloyd Layman

The Firechief's Handbook, Edited by James Casey

The Fireground Commander, by Chief Alan Brunacini, Phoenix Fire Department

Fire Suppression Rating Schedule, Insurance Services Office

Fireground Tactics, by Manual Fried

Initial Fire Attack, A seminar presented by the International Society of Fire Service Instructors

Fire Manual, Prepared by the Division of Civil Service (out of print)

Essentials of Firefighting, International Fire Service Training Association

Officers' Training Manual, Nassau County Fire Service Academy

Preface

Members of the fire service have often heard mention of the discipline concept and its importance to the organization. Unfortunately, the term too often is associated with the negative connotation, referring to punishment. It should be pointed out, however, that not only does discipline have a positive meaning, but is vital to the operations on the fireground.

Reference is sometimes made of a winning football team as having a well "disciplined" offense, because the pass patterns are run to perfection, or a professional hockey team as well "disciplined" because the wings skate their lanes and forecheck in the corners. This type of discipline comes from training, which leads to positive results; the more training, the more discipline. Just as profess-ional sport teams are referred to as having a disciplined organization, so the fire department must have a disciplined team to function effectively on the fireground.

A fire officer can expect success on the fireground only when he has at his disposal a disciplined, trained force of men and equipment to carry out the prescribed evolutions.

Just as important to the final outcome, however, is the fact that the officer himself must be disciplined to perform the functions of supervising the operations within h is authority on the fireground. It begins with the ability to remain cool and calm under the most adverse conditions, and is born through training that leads to a feeling of security within himself.

Fire scenes can sometimes severly tax the calmness of the best fire officers. The scene can become so complex with possibilities, with so many critical decisions necessary, that the officer has a problem accurately evaluating an effective defense. His background and train-ing must have provided him with a series of steps, which when followed, will cover all bases.

It is with this "check list" format in mind that the Order of Operations as first developed and printed in the former Massachusetts Civil Service Manual (Red Book). Its design was intended to provide the officer with

a method of making logical, sequential decisions, leading one step at a time toward successful confinement with safety being the predominant factor.

It is this format that this text will follow and expand upon, in an attempt to aid the fire officers of the Commonwealth in their efforts toward effectiveness and professionalism.

Size-up

Sufficient Help

Life Hazard

Exposure

Entry

Ventilation

Extinguishment

Salvage

Overhaul

PREREQUISITE FOR A PLAN OF OPERATIONS

Fire departments, like the military, must engage in in-depth techniques for developing plans for future combat. The military, before undertaking an offensive, will use reconnaissance patrols and intelligence reports to analyze enemy troop strengths and deployment, estimated resistance, terrain features, and many other factors that will provide the strategists with an edge toward a sustained offensive that will overpower the enemy. The plan is usually flexible enough to undergo rapid revision on the spot in the event of varying conditions. Like the military, fire departments must preplan operations in order to provide an edge for itself on the fireground.

Prefire planning has been defined as the plans made by a fire department regarding special hazards, in order that the department will be better prepared to do an intelligent, efficient job of firefighting. Pre-planning is fighting fires while they are still in the future.

Pre-planning generally takes the form of three steps:

<u>First</u>, a department thoroughly analyzes and documents the physical characteristics of its community target hazards. The specific risk of each hazard is determined, as well as the surroundings, that will impact on firefighting operations.

<u>Second</u>ly is consideration of the department's available resources and the effective strategy for deploying such resources to best accomplish an effective initial fire attack.

<u>Thirdly</u>, incorporating steps one and two into an ongoing training program will make the officer and men fully aware of such information and procedures.

The physical features of buildings and surrounding area are fixed factors that a fire department can do little to change on a short range basis. It is, however, the effort towards planning and training that often reflects in the fire loss figures of a community, thereby distiguishing one fire department from another.

Pre-planning enables a fire department to do the best job it can with the resources available.

The Order of Operations, as previously mentioned, provides a systematic "check list" of the basic factors that must be considered, not only for size up, but for decision making, and reviewing the progress of operations.

The decision making process has been likened to mentally flipping through an index card system; pulling out those factors that are critical to the fire problem, and taking the appropriate action. The Officer-in-charge, however, is capable of dealing with only a limited number of these factors at a time, as he is pressured into committing manpower and apparatus to a rapidly changing problem. Therefore, many of the factors must be predetermined, documented, and available for instant retrieval at the fireground. Such information is acquired, of course, through a thorough pre-planning program. Preplanning arms the officer with a battery of prior information that is necessary to eliminate confusion on the fireground; provide a basis for proper decisions; eliminate the number of mental file cards the officer must review, thereby reducing guesswork.

IF YOU ARE FAILING TO PREPARE YOU ARE PREPARING TO FAIL

It is through pre-planning that information such as building construction features, type of occupancy and storage, location of fixed systems, accessibility, and so many other factors that influence fireground decisions are analyzed, processed, and recorded for future referral. Pre-planning, used in conjunction with frequent training sessions, cannot be overemphasized for its usefulness in preparing officers and firefighters for effective fireground operations.

Although there are many areas where pre-planning can help the Officer-in-charge, as well as his entire complement of personnel, with his method of attack, one area in particular stands out as absolutely necessary - WATER SUPPLY. There are three factors necessary if the OIC expects to begin his strategy and tactics approach with a positive punch:

1. Determine the Required Fire Flow for the target hazard - what is needed.
2. Determine the volume of water available from municipal and static sources - what is available.
3. Evaluate and plan the fire department's capability to readily move and apply the available water.

DETERMINING THE REQUIRED FIRE FLOW FOR TARGET HAZARDS

One question that is uppermost in the minds of fire officers is, "At a given fire, how much water will be needed?" Before arriving at an answer, however, there must be an understanding of how the water is to be applied.

Water is used not only because of its availability, but also for its excellent absorption qualities, and is applied by means of either straight stream of fog/spray. Lloyd Layman's experiments were, at least in part, responsible for an awareness of the effectiveness of fog over solid stream application, where conditions permit rapid conversion of fog into steam. Fog, therefore, is generally the more effective due to the large surface area of the total quantity of water which is exposed to the heat, and therefore able to rapidly absorb heat.

Heat absorption is based upon the exchange of BTU's (a measurement of heat production) from the warmer substance to the cooler substance. The warmer substance, in the case of fire, consists of what is burning, and the atmosphere surrounding the burning materials. Since heat rises, within a confined or partially confined area, the heat will actually be "stored" above the fire area, making the area above hotter than objects actually involved in fire.

Science has determined for us that a cubic foot of air has a potential of producing 37 BTU's. Within an area, therefore, each cubic foot of space can produce 37 BTU's of heat. With this knowledge, we can easily calculate the potential BTU production by multiplying the BTU's (37) times the cubic footage. For example, in a room 10' X 10' X 7' high, we have 700 cubic feet of air. Multiplying this times 37 BTU's per cubic foot, we find the potential BTU's to be 25,000.

Further, the Law of Specific Heat has determined for us that a means of measuring how much heat must be removed to cool a substance to a safe temperature. Considering, as the Law determines, that 1 BTU is the amount of heat required to raise one pound of water one degree Fahrenheit, it therefore follows that one gallon of water (Wt 8.33 lbs) requires 8.33 BTU to raise the temperature one degree Fahrenheit. Assuming hose stream temperatures to be 62°F, raising the temperature of 1 gallon of this hose stream to 212°F will transfer 1250 BTU's from the warmer object to the cooler water. (212 - 62 = 150 X 8.33 BTU = 1249 [1250]).

In accordance with the Theory of Latent Heat of Vaporization, additional BTU's are necessary in the conversion process from liquid to gas. One gallon of water will absorb 1250 BTU's to get to 212°F and 8080 BTU's to turn into steam. Adding these together, we find that 8080 + 1250 = 9330 BTU's that will be absorbed to produce steam.

We must now arrive at a Rate of Flow, or gallons per minute. To do this, we will determine how many cubic feet will be effected by one gallon of water. If each gallon removes 7464 BTU, then we find that the area effected by this gallon can be expressed by dividing the BTU's removed by a gallon of water by the BTU's produced in a cubic foot of space. Or, 7464 ÷ 37 - 201 cubic feet, so each gallon will effect 200 cubic feet. [1]

Numerous test findings have proven that the most effective length of application is 30 seconds. Since 30 seconds is ½ minute, we divide 200 by ½ to arrive at 100. We now can express our knowledge as a basic formula:

$$\frac{\text{Cubic Feet of Area}}{100} = \text{GPM}$$

In addition to the cubic feet of area, there are a number of factors that will influence the Required Fire Flow. A "Guide for Determining Required Fire Flow" can be found in the Appendix of this manual, as well as a sample of the ISO Field Sheet for Calculating the flow. Generally speaking, additional factors include:

1. Type of construction and occupancy. The required flow may be reduced by up to 25% for occupancies having a low fire hazard, or may be increased up to 25% for occupancies having a high fire hazard.
2. Sprinklers. The required flow may be reduced by up to 50% for complete automatic sprinkler protection. Where buildings are either fire resistive or noncombustible construction, and have a low fire hazard, the reduction may be up to 75%.
3. Exposures. The required flow may be increased by a percentage according to the exposed building(s) within 150 feet. This percentage shall depend upon the height, area, and construction of the building(s) being exposed, the separation, openings in the exposed building(s), the length of exposure, the provision of automatic sprinklers, and occupancy.

[1] See Appendix, Guide for Determination of Required Fire Flow

NOTE: The total percentage shall be the sum of the percentages for all sides, but shall not exceed 75%.

The fire flow shall not exceed 12,000 GPM, nor be less than 500 GPM

FLOW TESTING

Once it has been determined what a particular hazard may require for fire flow, the planning stage should continue with a determination of what actually is available to the fire department in terms of water volume. A flow testing program should be undertaken that indicate what the mains are capable of delivering to the hydrants in the various areas.

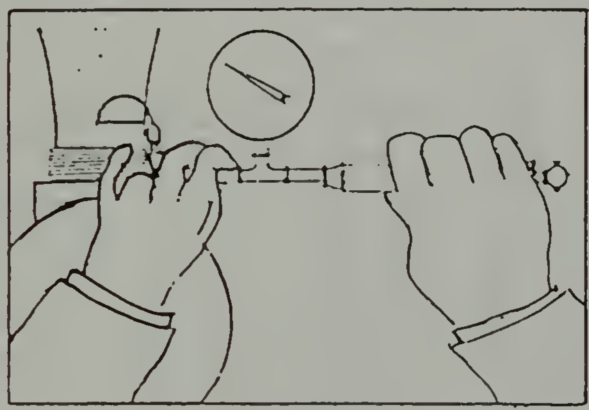
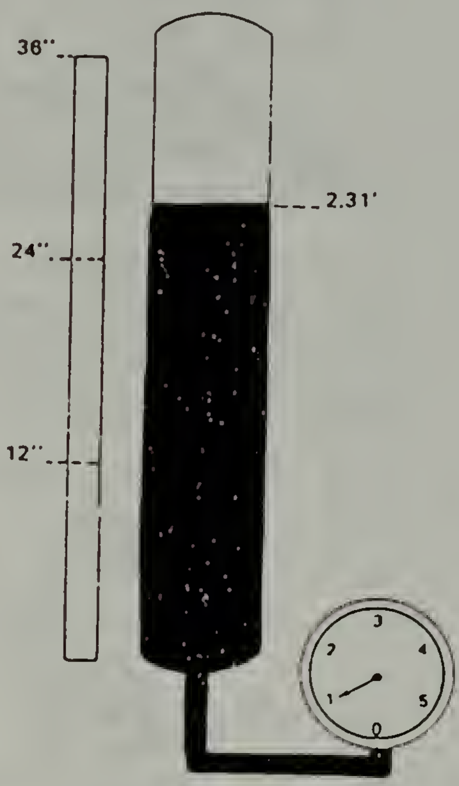


Fig 1

If, for example, a particular hazard is calculated to have a Required Fire Flow of 3500 GPM, flowing the hydrants in the area may indicate that the municipal system is capable of delivering only 1500 GPM. Under these circumstances, further planning will have to be developed for the supplementing of water, in the event of fire, from larger mains, or reliance on static sources. In either event, the fire department must have an accurate picture of the water resources available, to be adequately prepared for a fire incident.

In cooperation with the local Water Department, a program should be included in activities that will provide a knowledge of the capacity of the water system, as well as other information regarding the system that may be essential to establishing pre-plans.

STATIC PRESSURE



One Pound Pressure Equals 2.31' of Water

Fig 2

GET THE FACTS. In order to identify strong and weak points in the distribution system, the required data must be accurately determined and recorded. In order to do so, some terms and procedures must be understood.

1. Static Pressure. The pressure of water when it is not in motion. The stored potential energy that is available to force water through pipe and fittings, fire hose, and adapters.

2. Residual Pressure. The pressure remaining at a hydrant outlet after water is flowing. That part of the total pressure that is not used to overcome friction or gravity while forcing water through fire hose, pipe, fittings and adapters.

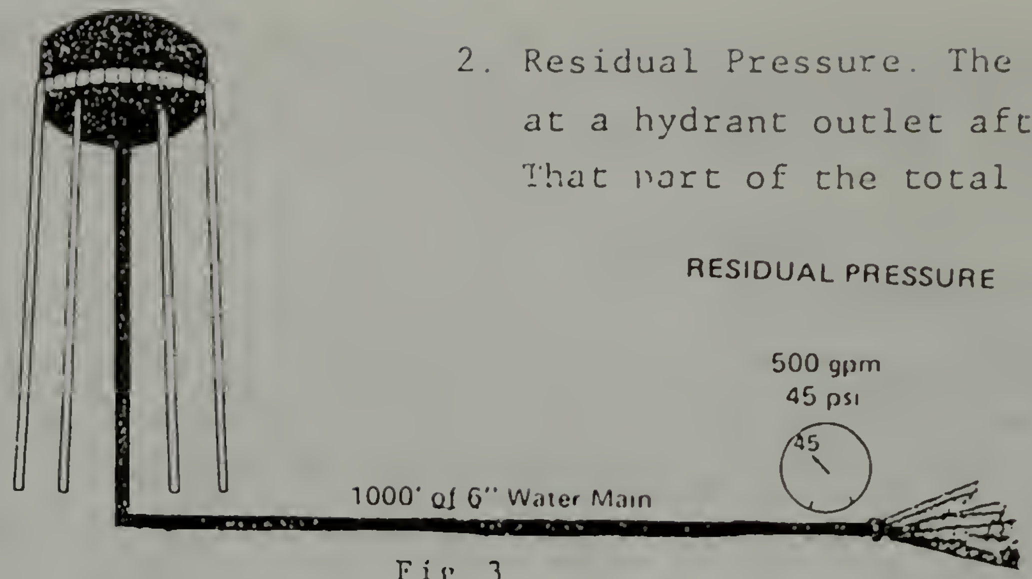


Fig 3

3. Flow Pressure. The pressure of water after it has been placed in motion. The forward velocity pressure at a discharge opening that is recorded by a pitot tube and gauge while water is flowing

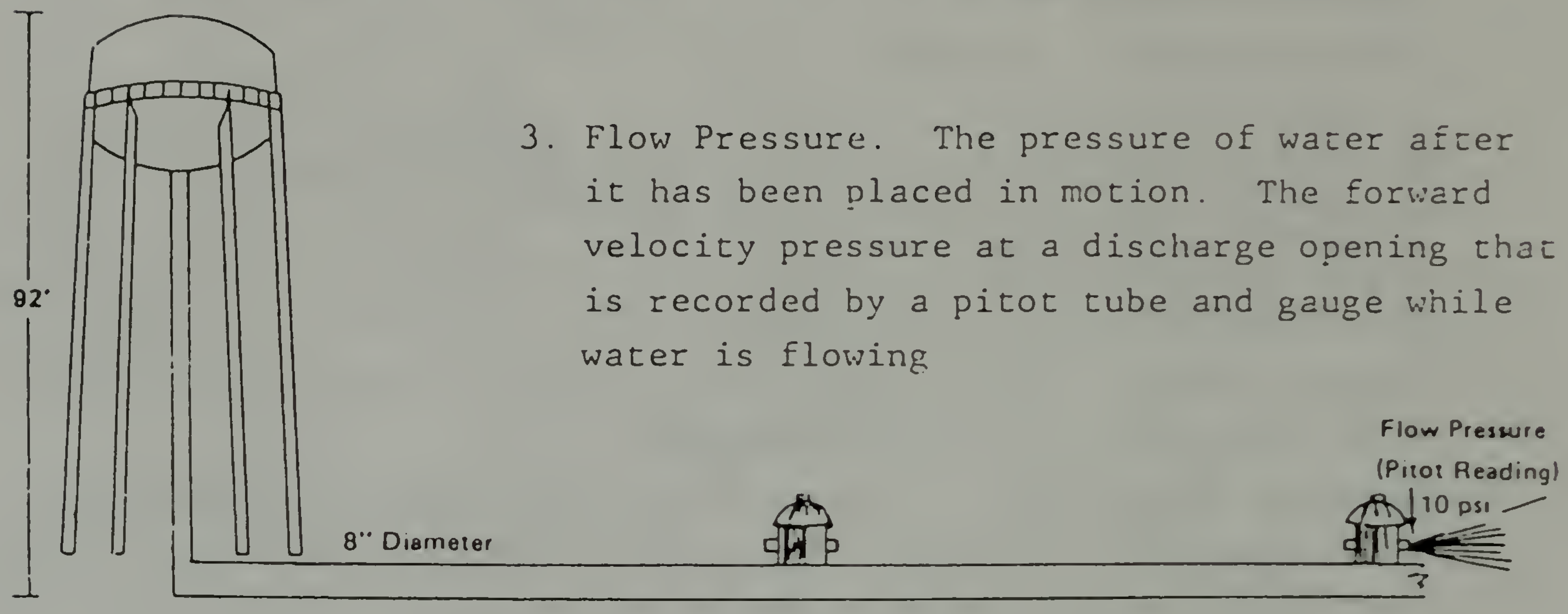
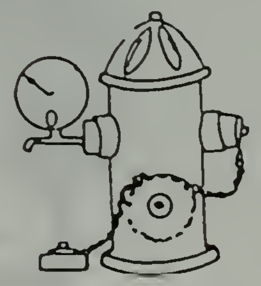


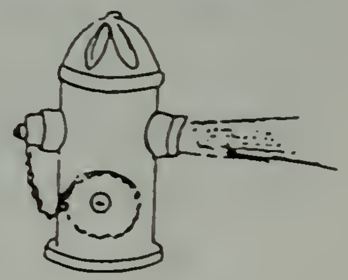
Fig 4

Steps For Conducting Flow Test. One or more hydrants should be opened for the flow, depending on the estimate of flow available in the area.

1. Place a gauge on hydrant #1. The hydrant stem will be opened and the Static Pressure recorded as indicated on gauge. For illustrative purposes, 60 lbs has been used as an example on the graph, next page.
2. Open hydrant #2. With pitot tube, record the Flow Pressure while other person(s) is recording Residual Pressure on Hydrant #1



Hydrant #1

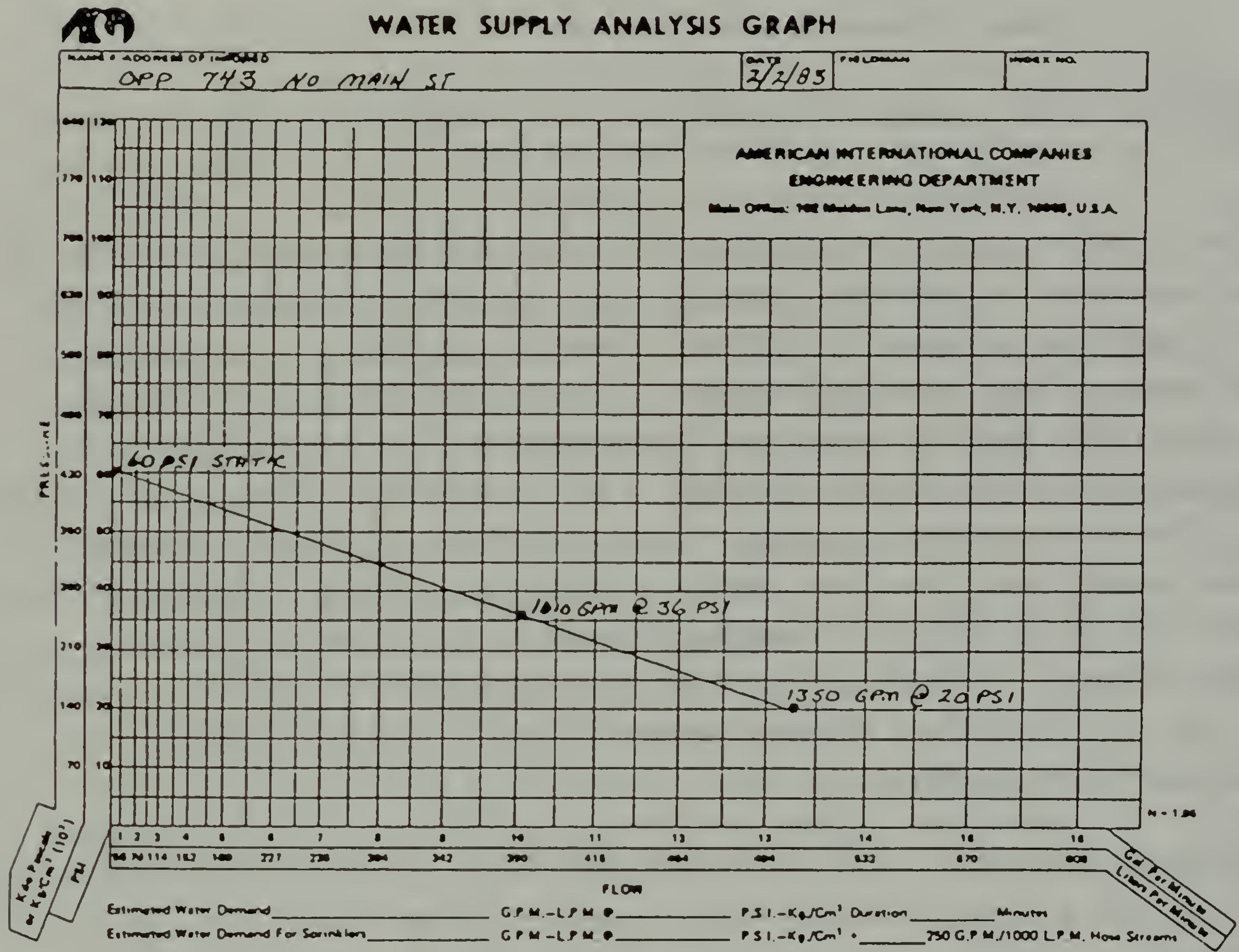


Hydrant #2

Figures 1-4, Courtesy of I.F.S.T.A, Manual 205

To compute findings:

1. Plot Static Pressure on graph.
2. With use of available charts, determine total flow from Residual Pressure.
3. Plot on graph the point where Residual Pressure and total discharge meet.
4. Draw a line from Static to Residual. Continuation of this line will indicate flow available at 20 psi.



Once gathered, all information regarding main sizes, pressures, and flows should be included in the training program and documented in such a way as to be retrievable under fire conditions. Color coding of hydrants according to the flow available is an excellent method of providing valuable information for fire operations.

Information regarding water flow cannot be over-emphasized as to its importance to pre-planning.
(Note: An excellent reference is NFPA's booklet SPP-66, Fire Flow Tests, Discharge Tables for Circular Outlets and Friction Loss in Pipes.)

EVALUATING INFORMATION AND PLANNING OPERATIONS

Suppression activities will be an array of actions begun after the fire has started. Its success, however, will be heavily influenced by what has been accomplished through planning, before the alarm. The Required Fire Flow not only provides a tool for measuring the fire problem of a community, but also can act as a tool for determining:

1. Manning levels
2. Apparatus response
3. Standard Operating Procedures

MANNING LEVELS. There is a direct relationship between an engine crew's manning level and the amount of water it can apply on the fire. In "Training Standard on Initial Fire Attack", published by NFPA, it is suggested that the first two arriving pieces of apparatus should be capable of putting into service two (2) 1½" attack lines flowing at least 150 GPM, within 60 seconds, followed by a 2½" back up line flowing 250 GPM, within 180 seconds of arrival. In requiring this initial 400 GPM attack within 180 seconds, the pamphlet does not commit itself to the number of firefighters needed. The most effective use of personnel resources will depend on local conditions, whether rural, suburban, or urban. Manning levels should be distributed to key apparatus in such numbers as to get the best sustained attack from first due companies. It must be remembered that on adequately manned company can out-perform two or three undermanned companies.

APPARATUS RESPONSE. It is recommended that the total available pumping capacity should be sufficient for the Required Fire Flow in the community. The fact is, however, what most of us have to work with on initial response is a far cry from the recommendations of the standard setters. In most cases, it comes down to having to make the best of inadequate resources.

How much water can the suppression personnel effectively apply? It is the responsibility of the OIC to know what he can expect from a company. Local conditions such as levels of manning and training will dictate capabilities. Although the Standard of Initial Fire Attack suggests a capability of 400 GPM within 180 seconds, realistically the three man company can initially put into service only one 2½" handline.

Determining the Required Fire Flow provides fire administrators with a means of measuring their capabilities against the potential, and planning and adjusting response accordingly. A close examination of the resources, as well as some experimenting with new concepts, may break through some of the traditional methods that should be streamlined. Modern concepts like large diameter hose, automatic nozzles, larger preconnected attack lines, and other innovations, may well serve to strengthen the attack.

Strategy and tactics, although tailored to general guidelines, will vary according to the problem and the resources available, and will be directly influenced by the manner in which those resources are deployed.

STANDARD OPERATING PROCEDURES. A Standard Operating Procedure consists of a number of predetermined steps, uniformly performed, to accomplish a specific task which is directed toward the objective - extinguishment. SOP's may be set forth regarding how engines will connect to a hydrant, positioning of apparatus, when SCBA will be worn, etc., each tailored to the needs and capabilities of the local department. The use of SOP's, once implemented through training, serve to enhance the tactics efforts by:

1. Standardizing operations throughout the department.
2. Reducing the number of orders and amount of attention that officers must devote to menial tasks.

The quality and quantity of pre-fire planning may one day mean the difference between a routine fire or a large loss fire. It is the training and planning process that will serve not only to reduce property loss, but reduce life hazard. THE BENEFITS OF PRE PLANNING DO PAY OFF.

Command Post

Many supervisors, fire officers included, have a tendency sometimes to revert back to a level of performance with which they are most comfortable. As an example, it is sometimes difficult for a new lieutenant to avoid the urge to be a nozzleman. For years he has been a nozzleman, probably a good one at that, and has always had that feeling of accomplishment in that capacity. Now, as a lieutenant, under fire conditions, he frequently has the urge to take the nozzle. Likewise, it is often difficult for the new chief officer, when assuming fireground command, not to enter the building and perform at a captain's level. He must, however, as the Officer-in-charge, recognize the advantage as well as the responsibility of establishing a command post at each major incident.

There is one person who has the responsibility of knowing as much of the complete picture of the incident as possible, the officer-in-charge. He may be the chief, deputy chief, or even at times a company officer, but as the commander of the fireground, he must position himself in a location where he can function effectively, be readily available to transmit and receive messages, and be capable of observing as much as possible of the scene. This location is referred to as a COMMAND POST, and is vital to the effective operations at a major incident.

The location selected by the Officer-in-charge to be his Command Post should provide:

A. Suitable vantage point to view the involved structure and area.
B. Visibility of the Command Post
C. Full communication capabilities
D. Access to supplemental information to support command decisions.

VIEW OF INVOLVED STRUCTURE AND AREA

The Command Post is generally established in the front of the involved building. It is this position that most often allows the Officer-in-charge the best view, not only of the progress of firefighting efforts, but also of related activities outside the building. It is from this position that the OIC can best evaluate the effectiveness of the needs for tactical decisions. It is from this position also that incoming manpower and equipment can come for assignment or information. It becomes a good practice for fire departments to establish as SOP, that once on the fireground of a major incident, the OIC shall transmit via radio, as soon as possible to fire alarm or dispatch center, "Command Post is being located at _____". This practice allows both incoming apparatus and apparatus already committed, knowledge of exactly where the OIC will be.

It is this early establishment of a CP that eliminates "Freelance firefighting" - that type of disorganized fireground operations where companies select their own priorities and duties.

Understandably, there will be situations where the best location for the Command Post is not the front of the building. The OIC will, as part of his size-up, determine the best location.

SECTOR COMMANDERS

Fires involving large buildings or large areas are very apt to strain the OIC's efforts to maintain Unity of Command at such fires, visibility to some areas may be impossible, and communications may be seriously restricted from sections of the fireground that require constant surveillance and progress reports. The fireground operation may, in some cases. be so large, that the OIC may have to delegate portions of responsibility, according to areas, to other officers.

At many fires, for example, the rear of the fire is one on the most critical areas of operation, yet beyond the control of a Command Post at the front of the building. Sectors may therefore be designated, in accordance with the chain of command. In such cases where the OIC is the Chief of Department, the rear of the building is usually

delegated to the Assistant Chief, or Deputy Chief, and other sectors delegated according to the size of the fire.

Orders should flow from the OIC to the Sector Commander(s), through them to the company officers in charge of crews. Sector Commanders may also give specific assignments to company officers in accordance with suggested tactics for operations under his responsibility and within his authority.

It will be the Sector Commander(s) who will serve as remote eyes for the OIC, and communicate necessary and appropriate information for the OIC to view the entire picture.

VISIBILITY OF THE COMMAND POST

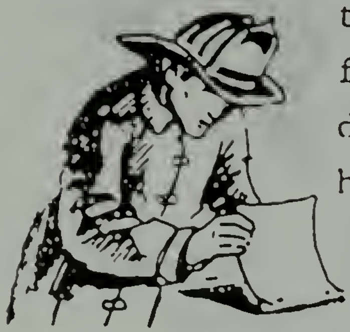
A critical factor of the decisions made by the OIC is the feedback he receives from inside the structure or other sections beyond his range of view. Visibility, therefore, becomes necessary in order that he can receive messages verbally and face to face.

Radio transmission of the location, plus good visibility of the site, allows the officers on incoming apparatus, if not assigned via radio. to report to the CP.

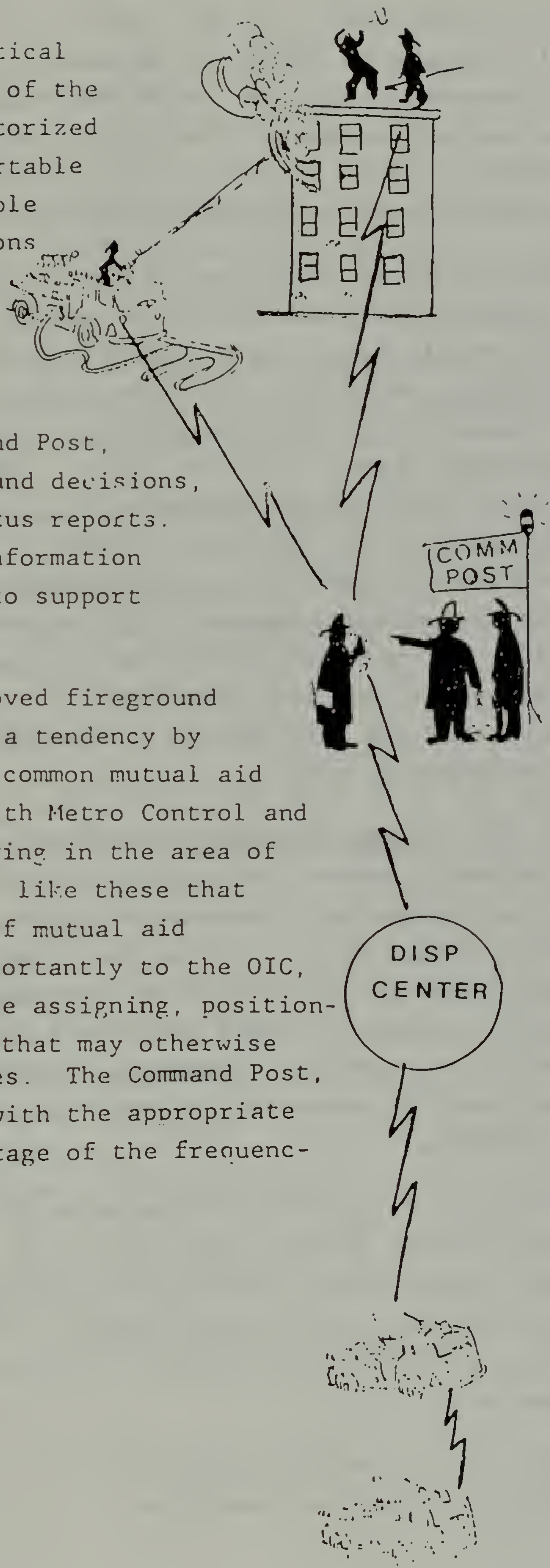
Some departments will respond a command vehicle, capable of the various functions necessary for the task, to the scene of large incidents. Some departments are establishing visibility of the CP by use of some type of distinguishing marker, such as a flag, on the command vehicle.

ACCESS TO SUPPLEMENTAL INFORMATION

Fireground decisions must, whenever possible, be based on fact. The more facts that are available to the OIC, the easier it becomes to form a plan of attack. The Command Post should, therefore, have the capability for instant retrieval of vital data relative to the structure involved. The OIC should have at his fingertips, information relative to such factors as building construction, including unusual building features, water supplies, fixed systems, hazardous storage or processes, access to utilities, and other factors that will influence decisions. The system for storing and retrieving such information on the fireground can be as simple as a note book, or as complex as a computer.



FULL COMMUNICATION CAPABILITIES



Communications is always a critical factor on the fireground. One of the greatest advancements since motorized fire apparatus has been the portable radio. Since the use of portable radios, fireground communications have been continually expanding and improving. It is this type of shared information regarding the progress of the fire, transmitted to the Command Post, that allows the OIC to make sound decisions, based on accurate, current status reports. Communication of appropriate information therefore, must be encouraged to support the overall fireground effort.

In a move to support more improved fireground communications, there has been a tendency by many fire departments to use a common mutual aid frequency. Such is the case with Metro Control and Southeastern Control, each serving in the area of 50 communities. It is networks like these that provide efficient dispatching of mutual aid apparatus, but perhaps more importantly to the OIC, a common radio frequency for the assigning, positioning, and coordinating of units that may otherwise be on separate radio frequencies. The Command Post, therefore, should be equipped with the appropriate radio facilities to take advantage of the frequencies that will be used.

SIZE-UP

At any incident, the most valuable moments for the Officer-in-charge will often be the moments taken upon arrival to evaluate the problem. Since the success of the entire operation will depend on the quick formulation of a plan of attack, based on his evaluation of conditions and circumstances, size-up becomes critical to future outcome.

The extent to which the OIC can accurately determine the true condition his forces face, together with his intuitive ability to translate the conditions into a strategic plan, will have a profound impact on the success of the attack. He must identify the critical factors, and prioritize the fire departments maneuvers to overpower the fire with a series of evolutions that provide not only support for the extinguishment phase, but more importantly, for the best protection of occupants and firefighters. In so doing, however, he is denied the luxury of time.

He must assume and exercise command, quickly formulating a strategic approach and issue direct orders that will be vital to an aggressive, coordinated attack. He must categorize first things first, in a series of evolutions that can be built upon by later arriving resources, remembering that once a decision is made and orders given, there is little or no opportunity to turn back, Decisions, therefore, must be based, as accurately as possible, on fact, training, and experience.

Prior knowledge through experience and preplanning will be contributing factors when the officer weighs the possibilities and probabilities faced on the fireground. Departments must consider the value of retrievable, documented preplans to equip officers with necessary information, thereby reducing guesswork.

Size-up will continue throughout the incident as the OIC reacts to changing conditions.

INTRODUCTION

I. Definitions:

  A. The mental evaluation of a fire problem or other emergency, which enables the person in charge to determine his course of action and to accomplish his mission.

  B. A conscious process involving the very rapid (but deliberate) consideration of the critical factors and the development of a rational plan of attack based on conditions present.

II. Responsibility of the Officer-in-charge of first alarm apparatus. (May be a firefighter in the absence of officer.)

III. Success or failure on the fireground depends on:

  A. Proper Size-up

    1. The ability to think clearly and logically

    2. Common sense

    3. The ability to maintain self-control

  B. The ability of men to carry out the operations directed as a result of Size-up.

FACTORS RELATIVE TO PROPER SIZE-UP

I. BEFORE THE ALARM

  A. Weather conditions

    1. Hot and humid - toll on firefighting force

    2. Rainy, damp

      a. smoke lays low

      b. venting difficult

    3. Snow/ice conditions

      a. delayed response

      b. hazardous working conditions

    4. Freezing temperatures

      a. toll on firefighters

      b. effect on equipment and apparatus

  B. Manpower available

    1. Vacancies due to sickness, injuries

    2. Vacations, layoffs, etc.

  C. Apparatus available - mechanical or other causes for shortage.

  D. Mutual aid availability

E. Miscellaneous

1. Temporary disruptions to water supply
    a. mains shut down for repair
    b. low pressure and/or volume due to excessive use
        I. hydrants open by citizens
        II. lawn sprinklers
2. Need for alternate response routes
    a. construction machines digging and blocking streets
    b. bridges closed for repair

NOTE: Much of the above conditions should be communicated to all personnel at the beginning of each shift and during each shift, either orally at role call proceedings, or through some type of written communication.

II. ON RECEIPT OF ALARM

A. Origin of alarm
1. Telephone
2. Street box
3. Automatic alarm

B. Correct address ascertained

C. Type of area
1. Residential
2. Business (industrial, manufacturing, mercantile)
3. Woodland, brush

D. Life hazard
1. Occupants
2. Firefighters

E. Preplanning (when call is for a specific location)

F. Response in accord with running card
1. Apparatus
2. Manpower
3. Preassigned mutual aid (line box, mutual alarm)

III. DURING RESPONSE

A. Response route
1. Distance apparatus must travel
2. Road conditions
3. Traffic conditions
4. Width of streets relative to positioning apparatus

B. Apparatus and manpower response
1. Special equipment necessary
2. Variations from running card (mechanical or other problems)

3. Diversion of apparatus to other call(s)

C. Water supplies (preplanning)
   1. Size of mains
   2. Pressure and volume in the area
   3. Hydrant distribution/locations
   4. Auxiliary sources

D. Fixed systems available
   1. Sprinklers
   2. Standpipes
   3. Others

E. Exposure problems
   1. External
   2. Internal

F. Alertness for radio messages
   1. Additional information from dispatch center
   2. Prior arriving apparatus

G. Other apparatus responding
   1. Common intersections
   2. Travel time

H. Previous experience(s) at address of incident
   1. Suspicious incidents
   2. Problem incidents

IV. UPON ARRIVAL

A. Facts
   1. Type of building
      a. construction
      b. size, height, area
   2. Type of occupancy
      a. life hazard (Time of day)
      b. fire load
   3. Extent of fire
      a. smoke or flame showing
      b. effective procedures - locate, surround, confine, extinguish
      c. Procedure with nothing showing
   4. Exposures
      a. external
      b. internal
   5. Establish command post - communications

6. Engine company operations
    a. apparatus placement - water supply available/needed
    b. line size selection
    c. line placement
7. Ladder company operations
    a. ladder selection and placement
    b. coordinate search, rescue, ventilation
8. Sufficient help
    a. fire department units
    b. ambulance or other medical assistance
    c. public utilities
    d. special help

B. Probabilities
1. Life hazard
    a. occupants
    b. firefighters
2. Exposures
    a. external
    b. internal
3. Weather conditions
4. Structural collapse
5. Explosion
    a. chemical
    b. backdraft

C. Possibilities
1. Loss of personnel
    a. exhaustion/fatigue
    b. weather conditions
    c. simultaneous fires
    d. injury - overcome
2. Loss of apparatus
    a. mechanical failure
    b. motor vehicle accident
    c. simultaneous fires
3. Reserve apparatus previously committed
    a. local manpower and apparatus
    b. mutual aid communities
4. Water supplies depleted
    a. unavailable
    b. damaged through sabotage or vandalism
5. Crowd interference

D. Resources - What do you have to work with?

1. Apparatus
2. Equipment
3. Personnel
4. Water Supply
5. Help (Utilities, police, etc.)
6. Fixed Systems

E. Decisions

1. Plan of action
2. Under stress and pressure
    a. orders must be clear and understandable
    b. communications must be adequate

V. DURING THE FIRE

A. Command delegation when possible

1. When conditions warrant. chief officer in charge of each side of building (Reporting to OIC)
2. Water officer
3. Communications officer
4. Public information officer

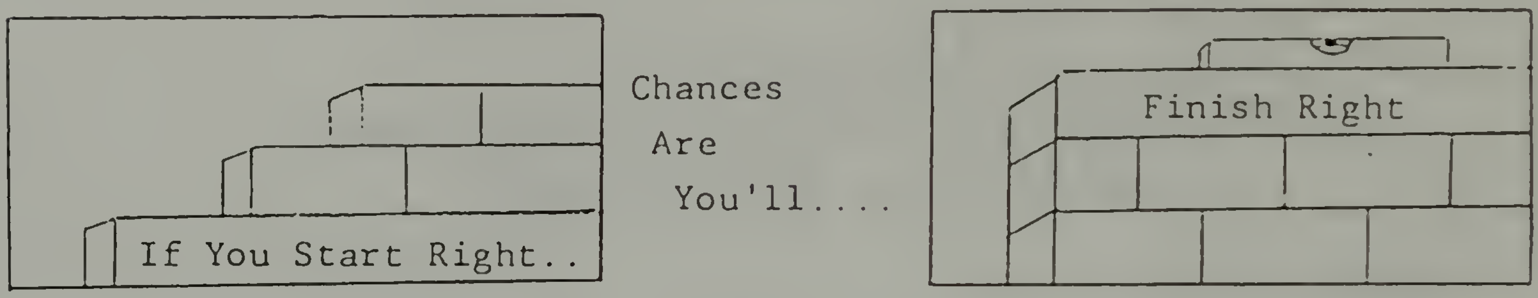
B. Communications - necessary feed back from company level operations inside

C. Adjustments

1. Safety
    a. need to withdraw
    b. structural threats
2. Time to step up to larger streams
3. Time to reduce down to smaller streams
4. Salvage operations
5. Providing for displaced occupants
6. Staging of incoming apparatus

Sufficient Help

It has been said that the first five minutes of a fire are worth the next five hours. Since the decisions of the first few minutes will set the tone for the operations to follow, early decisions must represent sound judgment on the part of the Officer-in-charge, and provide a foundation on which future operations can build. Like the mason laying block or brick, the first tier must be level for the top



to be level. One of the first critical decisions the Officer-in-charge must make concerns the need for additional help at the incident.

How much help is enough? If one were to ask how many men are needed to fight a vehicle fire, the answer could be from three to many. For a car fire three men could be enough, but a gasoline tanker in a congested neighborhood could require a multiple alarm response. So, to answer how much is enough, the job to be done must be determined during size-up, according to the type and magnitude of the incident.

Calling for additional help can be a simple choice, when a fire is of tremendous proportions and the need for additional help is obvious. It is, however, the fire where a choice of additional help is weighed against marginal fire conditions that present the most difficulty for officers.

The decision selected by the OIC will reflect his knowledge and experience; knowledge that provides him with the capability to recognize the various tasks that must be performed; experience that will serve as a yardstick for measuring manpower and equipment needs that were necessary for similar incidents in the past.

Generally, there are three principle factors that, alone or together, will determine if additional help is necessary.

1. Life Hazard
2. Extent of fire
3. Extenuating circumstances

1. LIFE HAZARD. If the life hazard exceeds the capabilities of the first alarm assignment, additional help will obviously be needed. Or, if the situation requires all or most of the first alarm response be deployed in rescue efforts, additional companies will be needed to perform other basic tasks, such as ventilation, placement of hose lines and ladders, to support the rescue effort. It is in these types of instances that the OIC must have the foresight to recognize the total picture of the incident.

2. EXTENT OF FIRE. As mentioned earlier, the decision to request additional help may be obvious upon arrival, or may not become apparent until after operations have begun. To further explain, the decision may fall within varying time frames:

- Immediately upon arrival
- A few minutes after arrival, as in the case of marginal conditions
- After initial operations, due to deteriorating conditions
- After fire knockdown

Even the newest, inexperienced officer will have little problem with the decision involving conditions that border on conflagration, but it is the marginal fire where an officer may have difficulty making a decision. In order to help the officer make the appropriate choice under such conditions, the following guidelines are offered:

A. If all first alarm resources are committed, stand-by back-up companies should be called to the scene.

B. When the OIC runs out of companies and still has assignments, request additional help. Often, the need may not be apparent until evolutions have begun.

C. In some cases of marginal fires, good judgment may suggest waiting until first water has been applied, and evaluating its effectiveness before requesting additional help.

D. There is no rule or guideline that will substitute for the intuition of the OIC, based on knowledge and experience, that additional help is needed. It has been said, that the first indication the OIC has that help <u>may</u> be needed - <u>call it</u>. The fact cannot be overemphasized that although delay may be justified in some instances, in most cases time is of the essence, and the OIC must react quickly.

Conditions will dictate the type and amount of help to be requested. It may be obvious to the OIC that a multiple alarm response will be

necessary. In other cases, as in marginal incidents where all first alarm companies are working, the OIC may feel the need of a single company back-up. In such cases, the single company should be requested. However, officers must try to avoid calling single companies one at a time, until eventually a second or third alarm response is on the scene. Fire departments must structure running cards to document multiple alarm response that clearly spells out response, and must discipline officers to use accepted department policy.

Perhaps the greatest concern to officers, regarding summoning additional help under marginal conditions, is the fear of, once called, not needing such resources. It should be remembered that it is far easier to justify why companies were called and not needed, than it is to explain why companies were needed and not called. Although an officer who continually asks for more help than is necessary may indicate an insecurity or inability of command skills, each incident must be judged on its own unique circumstances.

Most experienced officers have been in situations where there has not been enough help, as well as situations where there was too much help. Each of those officers will testify to the fact that he prefers the "too much" approach, which serves to eliminate unnecessary risks.

When considering the decision to request additional help, the officer should ask himself if he has assignments for arriving companies. Today's reduced manning levels, in some instances, may require that additional apparatus be called for the sole purpose of providing additional needed personnel, making very expensive pieces of equipment serve as personnel carriers. Before reaching for the radio, the officer may want to review some facts and probabilities concerning the incident, such as:

A. Manpower needed for initial search and rescue.
B. Line placement to stop fire extension.
C. How many hose streams of Required Fire Flow will be needed?
D. Pump capacity needed to move water at correct volume and pressure.
E. Requirements for ladder companies.
F. Command, maintenance, communication, and related support personnel.

3. EXTENUATING CIRCUMSTANCES. Under Size-up, there is note of the impact weather conditions have on firefighting personnel. Hot, humid days, or bitter cold conditions will take their toll on fire-fighters much earlier into operations than under normal weather conditions. Fires in multi-story buildings require fatiquing and exhausting efforts sometimes, simply to reach the fire floor. Under such conditions, where exhaustion has set in for one reason or another, the OIC should consider calling for help for the purpose of relief. In most cases, it is not reasonable for the same companies that made the initial attack to be on the scene hours later for the purpose of overhauling.

Manpower shortages, or simultaneous fires during busy brush fire season may so reduce initial response that help may be needed earlier than under normal conditions.

LIFE HAZARD

The Officer-in-charge must be capable of making accurate and appropriate decisions quickly; decisions that will affect the life safety of both occupants and firefighters. The success or failure of such decisions will usually depend upon the officer's ability to adhere to proper fire procedure. The Order of Operations provides the officer with a check list that can be followed for most fire incidents. Since life safety must receive first consideration by fire departments, it thus becomes the first item of proper fireground procedure.

OCCUPANTS

Upon arrival, the officer will base his size-up of life hazard on a number of factors, including type of occupancy, time of day, extent of fire and smoke conditions, and reports from spectators. Spectators cries, however, are not always an accurate indication of the true status of victims. Where an obvious life threatening situation is present, the officer must consider the following factors:

1. Number, location, and condition of victims
2. Seriousness of the fire threat to victims
3. Capability of rescue teams to enter, reach, and remove victims

Life hazard includes not only life endangered by actual fire, smoke, or heat, but also life endangered by panic. The prompt raising of ladders in the right places, complete and thorough ventilation, and the proper placing of lines have saved more lives than have spectacular rescues. Only where unusual conditions prevail, such as where people are hanging from or jumping out of windows should there be any departure from this procedure. If an engine company responds alone, and is without a truck company for a brief period of time, suggested procedure recommends running one, or in some cases, two lines to cut off extension of the fire and to cool down the atmosphere. The officer in charge must consider the life hazard and must calm the people at the windows until the arrival of the ladder truck. Too much stress cannot be placed on the necessity for prompt and proper ventilation, especially where the life hazard is severe. This point is particularly important before continuing with a discussion of life hazard.

PRIMARY SEARCH

It must be a standard procedure to implement a primary search in all structure fires, and all initial evolutions must be centered around the carrying out and completion of this effort. The effort and duration of the primary search will depend on a number of factors including occupancy, time of day, and reports from citizens. This search should verify the removal or safe egress of all occupants. In order to carry out this evolution, the OIC will have to make a judgment as to the feasibility of concentrating manpower on removing the victims from the fire, or the fire from the victims. In either case, consideration must be given to the advancement of a hose line simultaneously with rescue efforts. Such a line may offer protection to occupants by retarding fire advancement, or to firefighters who, under the stress and anxiety of the situation, may overextend their capabilities and suddenly need protection themselves. In multistory dwellings, this line may be advanced to gain and maintain control of the stairway, using care not to obstruct said stairway from the orderly evacuation of occupants.

Supplementary search may have to be made if a primary search is negative but evidence or conditions suggests searching must be continued. Whenever possible, fresh personnel should be used for subsequent searches.

Although suggested procedure recommends that ideally, fire control efforts should be carried out simultaneously with rescue efforts, reduced manning levels may require limiting manpower efforts to one or the other. It may not be uncommon for some communities to arrive with first due apparatus manning at two or three men total. Under such circumstances, the OIC must evaluate the manpower at hand quickly. If all the initial alarm manning will be committed to rescue efforts, regardless of manning strength, he must call for additional resources in anticipation of future operations and possibilities.

SECONDARY SEARCH

The primary search is principally concerned with time, where victims are immediately threatened, and search must necessarily be a concentrated effort during initial stages of fire operations. The secondary search is associated with that time frame follow-

ing fire control, when companies are able to make a more thorough search of the interior. It is at this stage of procedure, when visibility has improved and the atmosphere is more tenable, that rescuers pay particular attention to areas that may have been missed during the primary search. The OIC may want to consider using different personel for the secondary search than those who conducted the primary search, thus assuring some variation and overall thoroughness of the combined search effort.

SEARCH PROCEDURES

1. If heat and smoke prevent entry into an area, probe with arms, legs, and/or tools to determine if any victims are lying close to a door or window. Victims are frequently found near any means of exit, particularly near main stairways, windows, doors, or fire escape landings.
2. If it is possible to get in and search, look under beds, behind furniture, and in closets. Victims, especially children, often seek refuge in these areas.
3. One method of checking under a bed is to use your leg to gently sweep back and forth, feeling for a victim.
4. When conducting a search, have a plan. Do not just roam around. Plan to move from an entrance to another point of exit. This will often provide light and ventilation as well as an escape route for the searcher. Ventilate as you search, providing the spread of fire will not be increased by your efforts.
5. When searching bedrooms, some appropriate method should be used that will indicate to other searchers that the room has been searched, particularly in occupancies such as hotels, motels, and rooming houses. Suggested methods include: Securing a pillow case from a bedroom on the doorknob, or marking the doors with a large "X" in chalk.
6. Pre-planning and Standard Operating Procedures can be of immeasurable value during search procedures in multiple occupancies such as hotels, apartment buildings, etc. Keys, for example, should be available to the fire department for quick access to rooms. (Caution: The member with the key should not enter the room(s) being searched in order to provide availability of the key.)
7. When searching, stop and listen from time to time for sounds of coughing, crying, or moaning, which may indicate the location of victims. On the other hand, victims that can't be heard may be in the most serious danger.

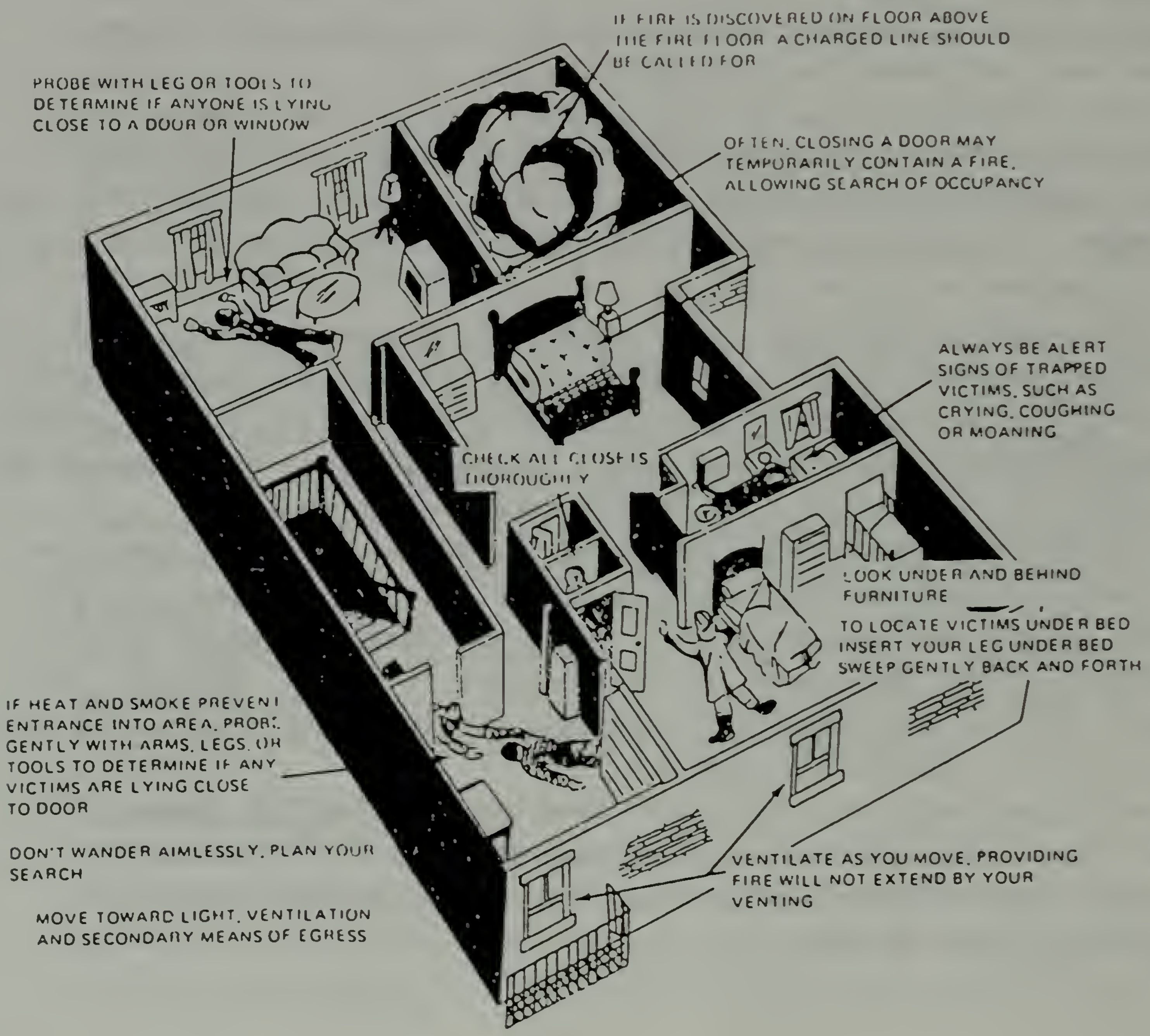
8. When entering for search, check for the presence of fire as well as for victims. Often the closing of a door will retard the spread of fire or assist in completing the rescue.

9. Guard against victims returning to the building after rescue or evacuation. Many victims return to save pets or to retrieve valuables. Placing evacuee under the control of police officers may avert a second search and rescue.

10. Reports that victims are safely out of a building is no assurance that this is true. Always assume that one or more victims may still be in a building until all are accounted for. Report the results of your search to the OIC.

11. The search starts on the fire floor as soon as entry can be made. Move to upper floors as quickly as possible. Upper floors may be the most dangerous are due to the vertical spread of heat, smoke, and gases.

SEARCHING HINTS

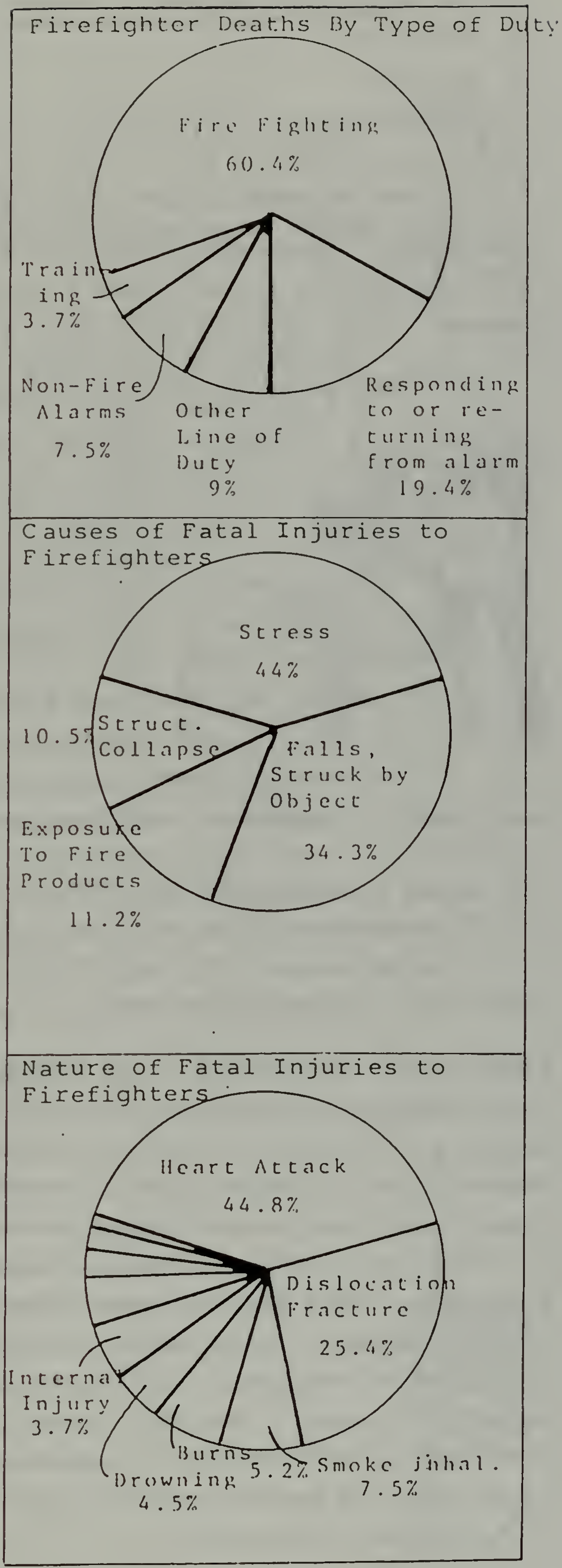


FIREFIGHTERS

According to the United States Department of Labor, firefighting has traditionally been the most hazardous occupation in this country. In-the-line of duty death each year hover close to the 100 mark, and today's firefighter still faces a better that 40% possibility that he will be injured at least once during the year. These death and injury statistics are unacceptable. Furthermore, the numbers, although not entirely preventable, can be reduced through more concentrated efforts in the areas mentioned below.

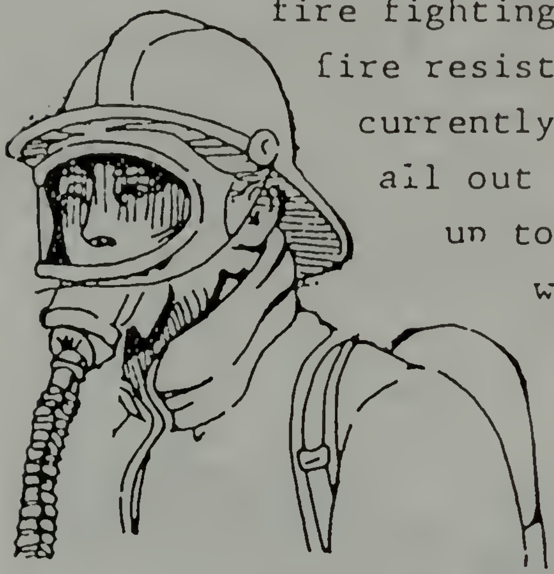
The "Firefighter Mortality Report" prepared for the National Bureau of Standards by the International Association of Firefighters is a 15 month study involving the investigation of 101 firefighter in-the-line of duty deaths. By extensively investigating each death, specific problem areas can be revealed, and serve as a starting point for launching further research. The text should be required reading for each and every officer in the fire service.

The report, in its entirety, demonstrates that safety is a combination of things. For the purpose of condensing and analyzing the report, there are six general catagories to discuss:



1. Equipment, Protection
2. Experience
3. Training
4. Communications
5. Manning levels
6. Officer Responsibility (Accountability)

EQUIPMENT. In general, protective equipment - improper use, non-use, and/or insufficient equipment - played a role in a number of the smoke inhalation and burn cases. Sadly, most fire fighting clothing in use today is not even fire resistive; a problem the fire service is currently dealing with. Until recently, almost all out protective clothing was black, from boots up to helmet, and not at all conducive to night work. It is these types of inadequacies that the officer must realize, and the fire service must correct.

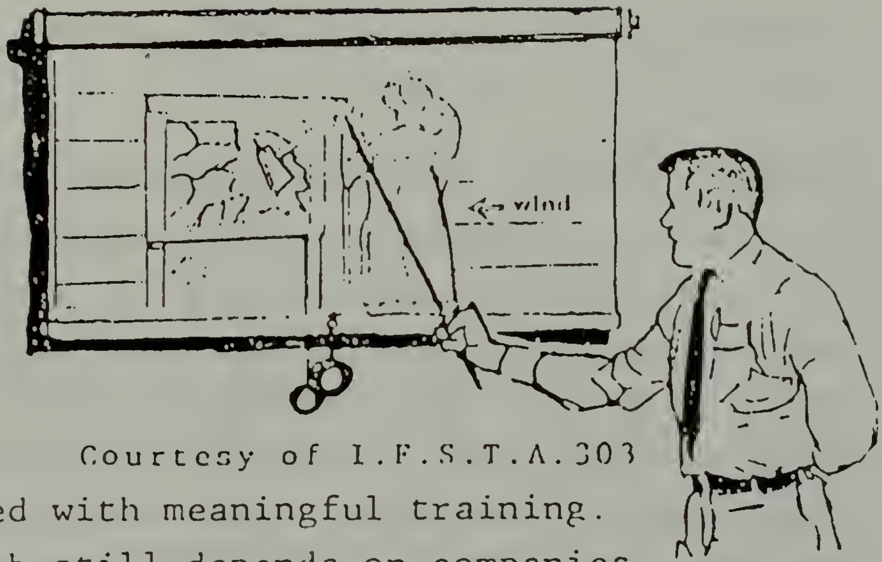


The first step for any fire administrator is to investigate the market and make every effort to provide for his men the best possible equipment his budget will allow.

Secondly, a department SOP must be established and enforced, that prohibits members from entering the fire area without full protective clothing, or into a hostile atmosphere, without self contained breathing apparatus.

EXPERIENCE. Of the 101 cases studied, close to one-third of all firefighters killed while fighting fires (excluding heart attacks), had five (5) years or less experience. These statistics strongly suggest that there is often a correlation between experience and fireground fatalities. Many fire officers have undergone an experience when moments before a backdraft or partial collapse of a building, they "sensed" something was wrong, and ordered their men to evacuate. This sixth sense appears to be something that is developed by more experienced men and officers - a feeling when danger is closest. The OIC, from his observations and communication feedback, coupled with his experience and judgment, will determine when the risk factors outweigh any advantage to further offensive firefighting efforts.

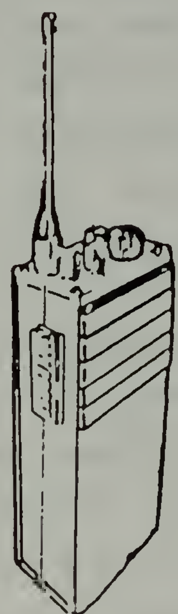
TRAINING. Relative to safety factors and synonymous with experience is training; the two go hand in hand. No fire department is so busy with its suppression activities that firefighters and officers can rely on the work alone for their learning.



Courtesy of I.F.S.T.A.303

Experience must be supplemented with meaningful training. The practical aspect of the job still depends on companies operating as a coordinated team. Therefore, it takes a combination of hands-on training in each evolution, plus perceptual knowledge, to perform safely and anticipate unsafe conditions. Fire situations, although each is different, have a tendency to be repetitive, However, it is not uncommon for an officer to encounter a situation that he has never faced before - a situation where initial decisions are critical. His decisions should be based on common sense and training - training that allows him to weigh the risk factors of a particular decision. As an example, a train derailment in a rural area, with no exposure problem or further explosion possibility, may require no action but complete burnout, rather than risk manpower inside a blast area. Hazardous Material training today stresses these basic fundamentals based on past experiences. Especially during structural firefighting situations, training and preplanning can provide an awareness of conditions that threaten the life hazard of firefighters.

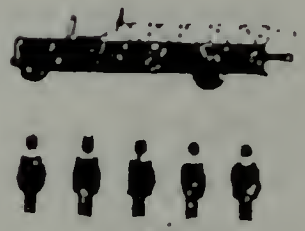
Training is vital to safety. However, to be effective, it must be accompanied by the necessary motivation to use the knowledge.



COMMUNICATIONS. The best available protection against death or injury is knowledge - information. As discussed, methods of acquiring it include experience and training. Another is through frequent, current reports on the fireground. Communications play a vital part in the decision making process, and the Officer-in-charge must rely on feedback from company level operations to help determine the risk potential. It therefore becomes essential for each fire department to encourage good communications on the fireground; communications that will provide the Command Post with the necessary information regarding

changing conditions which may warrant altering tactics for the sake of safety to personnel.

MANNING LEVELS. Few fire departments have enjoyed the luxury of a six man engine company. Some departments today are manned with an officer and two firefighters per company. The effectiveness of such manning is analyzed in the Dallas Study, as discussed in the text "Managing Fire Services. (Reference is made to these figures for illustrative purposes only.) Using six men as 100% effective, reductions in manning were determined as follows:



Five men.......80% effective

Four men.......52% effective

Three men......32% effective

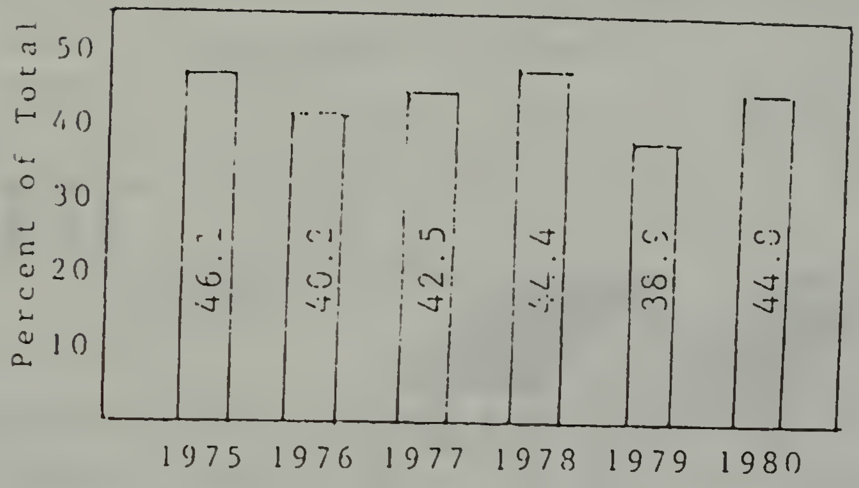
Three member crews are only 32% effective as six man crews, but what the study does not take into account is the extra work load passed on to the reduced crew. It is when these men instinctively undertake tasks beyond their capabilities (in the absence of adequate manning) that accidents and injuries occur. Fire administrators must tailor their response and operations to evolutions that will take advantage of teamwork. Evolutions assigned to individual companies should be tailored to effective utilization of the manpower on those companies. Consideration, therefore, should be given to the advantages, from both the efficiency and safety standpoints, of one adequately manned company over two undermanned companies. Safety should not be compromised because of reduced department strength.

The exertion, stress, and fatique of normal firefighting duties places an abnormal tax on the firefighter's body. His endurance is further restricted by having to wear approximately 50 lbs of protective clothing and equipment. It must be remembered by officers, that firefighting personnel are particularly vulnerable to accidents after fatique has set in and endurance limits reached.

Physical fitness has always played an important part in the performance of firefighters. Reduced manning levels only place added problems onto those already present. Figures show the nature of most of the fatal injuries to firefighters on the job is related to the cardiovascular system. Almost half the In-the-line of duty deaths annually are attributed to heart attack.

The death and injury reports of the past years show that, in proportion to other categories, heart attacks have accounted for between 40% and 50% of the deaths. The seriousness of these statistics reinforces two points:

Proportion of Deaths From Heart Attacks

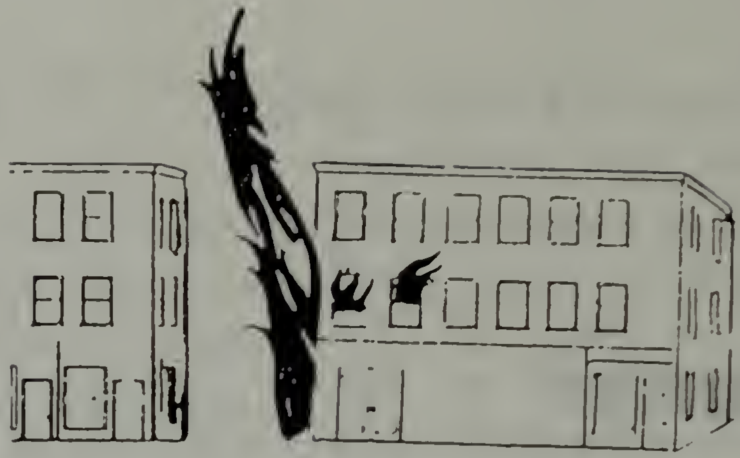


A. Years of exposure to stress, plus carbon monoxide and othe products of combustion place a heavy toll on the firefighter's circulatory system

B. The physical conditioning of firefighters must be maintained in order to reduce the risk presented by stress of the work environment.

OFFICER RESPONSIBILITY. In summary, the officer is responsible for the operations of his men. When the OIC sets up his Command Post at a selected vantage point, he does so with the understanding he must have control of the scene, including safety. The fireground must be as organized as possible, with the OIC maintaining control. Training should foster discipline; discipline that permits firefighters to understand initiative is encouraged, but actions must be planned, systematic, and coordinated, under the control of an officer. Too often, firefighters begin free lancing on the fireground, become detached from their company, and wander. It is this type of lax discipline that courts disaster. Officers must be accountable for their men, and recognize signs that may indicate unusual hazards.

EXPOSURES



EXTERNAL EXPOSURES

An external exposure is defined as a building or object, which is either adjoining or adjacent to the building in which the fire originated, but completely independent thereof.

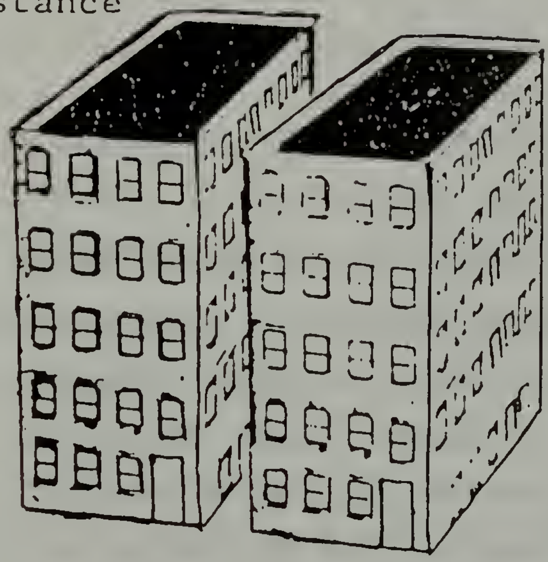
The assumed objective and basis for all firefighting strategy is to confine, control, and extinguish fire. The prime focus at incidents involving external exposures should be prevention of extension. Prevention efforts may take many forms, but the most commonly used is direct water application. However, in some buildings, protective devices are provided which could prove to have greater effectiveness, either by themselves, or in conjunction with water application. The OIC should, therefore, consider building features and devices that offer support to the confinement effort where buildings are exposed. As an example, some buildings are provided with exterior sprinklers for exposure protection. Wired glass windows in metal frame are often installed in buildings where exposure fire may be expected. Such devices must receive attention from the OIC under fire conditions, either by augmenting the system with pumped lines, or assuring windows, as well as doors and other openings are closed. If exposed buildings are equipped with standpipes, companies can attach hose lines to them on each effected floor and extinguish any burning window or door frames as well as other combustibles within the radiated heat zone. These lines may also be used to attack the main body of fire across the street or alley. Although exterior extension is usually less likely than interior extension, the exterior problem is of critical importance due to the fact that the consequence could be much more severe.

Depending on the severity of conditions, the exposure may only require a single line for precautionary wetting down on one side, or may require the commitment of the entire first alarm resources to all four sides of the fire building. It is important for the OIC to recognize, under certain conditions, he must be willing to initially "write off" a fully involved building in favor or prot-

tecting seriously exposed buildings. Also, for consideration, is that exposure hazard may be so reduced by effective initial effort- that fire conditions may allow streams to be redirected onto the fire building to reduce further heat generation.

There are a number of factors which will influence fire spread to the exposed buildings, and must be considered by the OIC.

A. First and foremost is the separation distance between the exposed and the exposing building(s). The extent of fire severity on arrival, combined with the separation distance between the fire building and the exposed building(s) influence the over-all severity of the exposure problem. Exposure to horizontal radiation of heat is proportional to distance.



B. The size of the exposure in relation to the fire building is also relevant to severity. The exposure problem will increase or decrease proportionally, depending on whether the exposed building is smaller, equal to, or greater in height than the exposing building. Heat and flame evolving from the fire building will have a natural tendency to rise in the atmosphere. Taller exposures, therefore, become more susceptible to ignition than do shorter exposures

C. The type of building construction will influence the susceptibility to ignition. The type of construction of the exterior walls and roof of the exposed building will have a great influence on combustible potential, as well as the number, size, and condition of wall openings. Built-in protection of these openings, if properly maintained, can greatly reduce the risk of exposure fire.

D. Weather conditions may contribute substantially to the extent of the fire problem. In cases where fire is overlapping and exposing other structures, the problem will be directly affected

by the direction and rate of fire travel, which in turn will be determined by the wind direction and velocity. Therefore, in order to halt the external progress of a fire, the OIC will have to evaluate and react to the wind factor. In cases where buildings are exposed, consideration will usually be given to the leeward side as a priority for coverage. When a spark and brand patrol must be established, the wind direction will be the determining factor for placing such a patrol.

Susceptibility to ignition will be increased when buildings have been subjected to prolonged dry spells, in contrast to their condition during wet weather.

When positions have been chosen for master streams to protect exposures, streams should be swept over the face of the exposed building, using care to wet down, yet not break exposed windows. Streams can be used also to hit the main body of fire as well as keeping the exposures cool. This is a point which is sometimes misunderstood. Remember, the prime objective is to extinguish the fire. Water need be only applied to the exposures to keep them successfully cool and the remaining time be used for direct application on the main body of fire. This practice serves to extinguish the fire as well as wetting down the exposure.

Two points must be remembered when using heavy streams for such protection. First, to insure that such use does not result in the breakage of windows in the exposed building(s), which would only increase the hazard. Secondly, such streams should be directed to keep the entire surface area of the exposure wet by direct water contact. The reason being, that radiant heat, although not capable of passing through opaque (non transparent) objects, will pass freely through water droplets and glass windows. Direct water contact on the exposed building is much more effective than the traditional water curtains between buildings.

INTERNAL EXPOSURES

Anytime there is a fire within a structure, some unburned portion of that structure is being threatened by fire extension. Some portions are immediately exposed; others may be involved at later stages of the fire. In either case, it is these unburned portions which may become involved in fire within the fire building that are considered INTERNAL EXPOSURES.

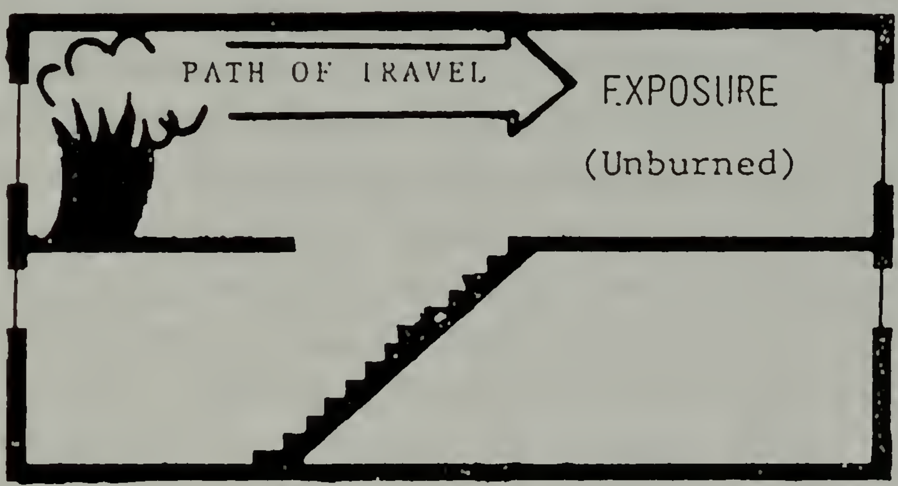
In order for the OIC to make appropriate decisions relative to the placement of interior hose lines for fire confinement, two factors must be accurately determined to the best of his ability:

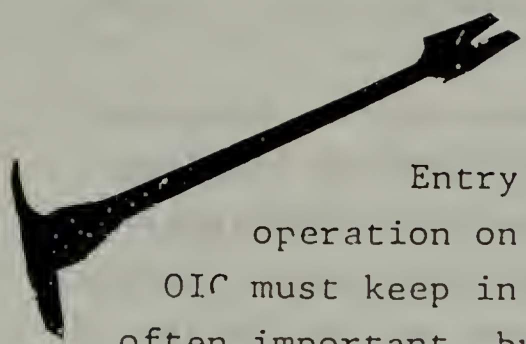
1. The path of fire travel
2. The most severe internal exposures, based on path of travel

To best evaluate the seriousness of internal exposures, the OIC will first have to determine the path of travel, or the route that fire is following, influenced by a combination of the natural flow of products of combustion and building features. The extent of fire upon arrival will be influenced by the intensity and rate of travel. Size-up should provide substantial evidence of such factors before a tactical plan can be implemented for effective confinement.

Once the OIC has determined what general path of travel the fire is taking, he must further analyze the location and degree of threat to internal exposures. It is rapid communication from internal company operations that provide the basis for future tactical decisions.

The basis for an effective tactical plan of attack will be to successfully surround and confine the fire, according to the degree of accessibility for proper line placement, to cut off extension to the internal exposures. Proper attention, therefore, must be devoted to the difference between burned portions of the structure and unburned portions, focusing on approaching from the unburned side, cutting off internal exposures from further fire advancement. It is only through recognition on the part of the OIC, of internal exposures, and efforts to protect such exposures, that leads to effective internal firefighting.





ENTRY

Entry is a critical operation on the fireground. The OIC must keep in mind that not only is timing often important, but also the method and the preparedness of personnel.

Entry into a building for investigation or attack is sometimes an unobstructed process of simply opening unlocked doors. However, it can also involve the tedious, challenging task of forcing locked and barred doors; even using cutting torches or pneumatic tools. Forcible entry procedures, therefore, must be taught and reviewed at all levels in the training program.

As with other fireground operations, proper entry procedures will be based on sufficient size-up of conditions. Once the OIC takes the time to evaluate conditions, some facts relative to entry will become obvious, such as:

1. Particular precautions may be required due to existing conditions. As an example, if possible backdraft is indicated, as discussed in the Ventilation section of this text, normal entry procedures will have to be altered until top level ventilation can be accomplished. Under such serious conditions, personnel must be aware of the possibilities occurring upon initial opening at ground level, and take the appropriate precautions for their safety.
2. In cases where any degree of heat or smoke are evident, a charged line must be in readiness before entry is attempted.
3. The place of entry may be obvious upon size-up, depending on what level and side of the building fire or smoke is showing, and taking into consideration operating from the unburned side. Where doubt exists concerning the point of entry, especially in dwellings, the option should be made in favor of the front door, or where access to the cellar or upper levels are generally close by. Experience with predominant type of building construction in the local community will serve as a guide for best points of entry.
4. The type of incident will dictate who and how many personnel will be entering the structure. It should be a policy of

every fire department that no one shall enter the building unless they have:

A. AN OBJECTIVE. Only those people who have a direct assignment shall enter. Especially during investigation type incidents, efforts should be made to discourage crowds of firefighters parading through the living room and across expensive carpets for the sake of curiosity. It will be the responsibility of the OIC to bring with him only those personnel needed to accomplish the task. Others should be in appropriate stand-by positions outside, ready to provide support activities if needed. In more serious incidents, well disciplined training will provide an awareness to personnel of responsibilities, whether it be search and rescue, attack line , ventilation, or other assigned task, and only those people with such objectives shall enter.

B. FULL PROTECTIVE CLOTHING AND EQUIPMENT. The number of injuries sustained by firefighters in-the-line of duty can be attributed to various causes, but lack of proper protective clothing is frequently a contributing factor. The fire service must see further advancements in the development of safer, lighter protective clothing;better suited for the task. However, personnel must also be educated to the value of using existing equipment. "Proper use" is intended to mean <u>complete</u> protection, from helmet to boots, including gloves and self-contained breathing apparatus, with boots all the way up, collars up and ear flaps down, dictated by a local policy that is enforced. There simply is no other way to provide full protection in a hostile environment.

C. NECESSARY TOOLS. The necessary tools to perform the task must be carried into the problem area. This is often overlooked during investigative type incidents, when, once inside, it is determined that an ax, or handlight, or other tool is required. Not only is it sometimes not on site, but when requested, members must return to apparatus to get the needed equipment.

There are also a number of other considerations that should be taken into account at the entry stage of operations.

1. A basic axiom to be considered when discussing forcible entry is "TRY BEFORE YOU PRY". Although it is recognized that some conditions will warrant the fast forcible approach, means other than forced may also be available, and less critical incidents may allow time to look for alternatives. A quick survey of common areas used for hiding house keys may prove worth while. Such areas include under the porch mat, on top of door casings, under the front steps, etc.

   Most fire departments make arrangements for the safe storage of keys to business, industrial, and public buildings, for use under emergency conditions. Entry key availability may not only prevent unnecessary property damage during minor incidents, but may minimize the entry problem during more serious incidents. There is evidence of public awareness to this problem by the trend toward use of on property "lock box"; a safe type box designed for the safe storage, yet accessibility to fire personnel, of keys. Fire personnel, however, must recognize their responsibility connected with the use and security of such keys.

2. The method and means of entry are most often dictated by conditions facing the attack crew. Where an option exists, and time allows, a window may be a more appropriate means of entry than forcing a door.

3. During pre-planning, consideration must be given to business, manufacturing, and industrial buildings that use attack dogs (note responsibility of owners as set forth in Chapter 148, GL). Documentation should be provided of such locations so that firefighting crews can be so notified before entry. Local departments should establish guidelines to govern decisions relative to such situations.

4. Also documented during pre-planning should be information relative to security guards. Not only should their employment sites be known, but these guards must be educated to their responsibilities and authority regarding:
   A. Notifying the fire department immediately upon any receipt of alarm or detection of fire.

B. Assisting the fire department with entry by providing passage through gates, doors, or other obstructed or locked areas.

C. A reminder that only the fire department has the authority to shut down sprinkler systems once operated, and leaving the resetting of fire alarm systems to the fire department. (The responsibility for final restoration of such systems rests with the owner.)

D. Operation of fire protection devices, such as smoke or fire doors.

E. To provide whatever first aid firefighting methods that may be appropriate, within safety limits, after notifying the fire department.

NOTE: In cases where either dogs or security guards are on the premises and suspicion prevails that they might not have been alerted to the fire department's entry efforts, crews performing initial entry should make lots of noise <u>immediately</u>, to prevent "surprises".

5. In multiple occupancy buildings, such as garden apartments, hotels, or motels, a master key will be necessary to conduct a complete search, as dictated by smoke and fire conditions. During search procedures in these structures, the firefighter or officer with the master key should not become actively involved in searching rooms. A faster search of a large number of rooms may be expected if the member with the search key (master) does not actively search the rooms.

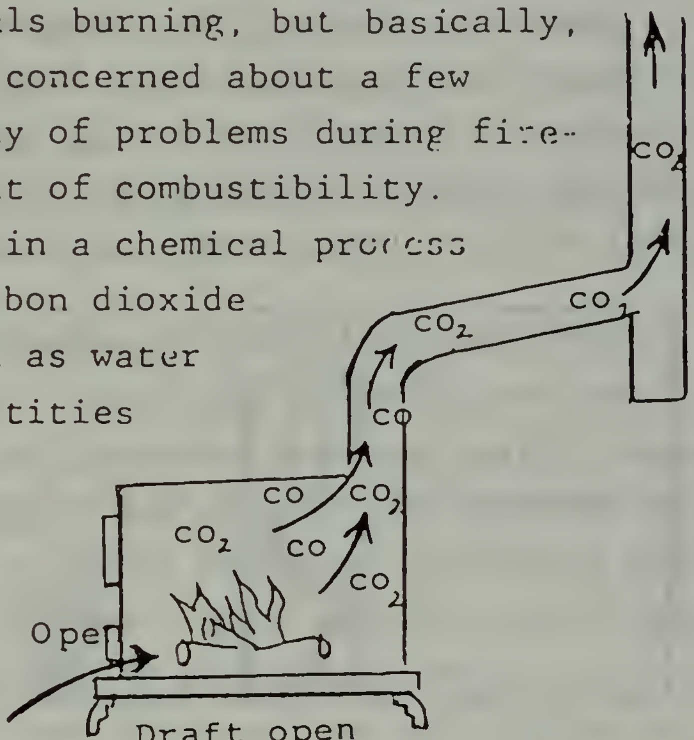
VENTILATION

Ventilation is the planned and systematic removal of heat, smoke, and gases from an involved building or area thereof, and its replacement with fresh air. It can be a complex operation that sometimes reduces fire extension more than the placing of hose lines, or, if delayed or improperly performed, can contribute to the rapid extension of fire. Since delayed or improper ventilation can be accountable also for a large percentage of injuries and even death to both occupants and firefighters, it is imperative that fire officers have a thorough understanding of this step in the Order of Operations.

Fire departments can not perform effective fire suppression without performing proper ventilation. In order to perceive the need, timing, and method for ventilation, the fire officer must first take a look at conditions that lead up to the opening up operation.

CHEMISTRY OF FIRE

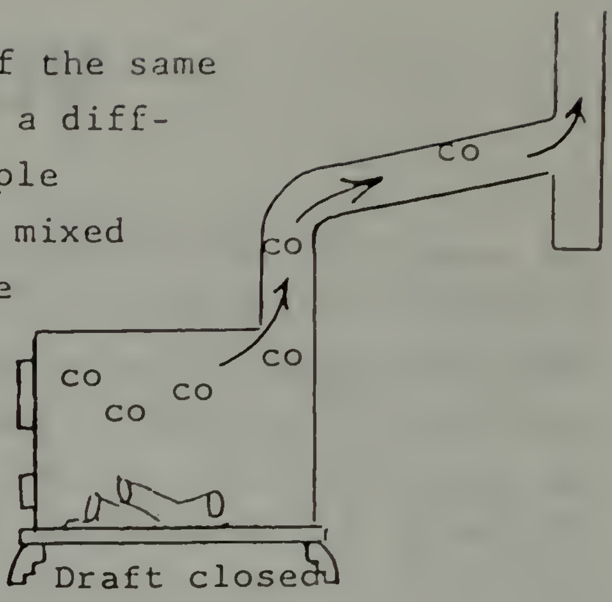
A look at the basics of the chemistry of fire indicates that the oxidation process known as "fire" is the rapid combining of oxygen with the various fuels, emitting light and heat as well as numerous products of combustion. These products may vary from one fire to another, depending on the materials burning, but basically, the firefighter and officer must be concerned about a few common gases that create the majority of problems during fireground operations from the standpoint of combustibility. Usually, a Class A fire will result in a chemical process with the principle product being carbon dioxide ($C + O_2 = CO_2$). Other products such as water vapor, tar particles, and minor quantities of carbon monoxide will also be produced by the free burning fire.



Draft open allows for free burning with little smoke

Under tighter, or closed conditions, as the oxygen in the atmosphere feeding the fire is reduced by the burning process, there is a change in the products of combustion. The process becomes the union of C, in the carbon based material with an oxygen deficient atmosphere, best illustrated as

C + O = CO. Carbon monoxide, a member of the same family as carbon dioxide, yet a horse of a different color entirely, becomes the principle product. CO is toxic and explosive when mixed with the right proportions of oxygen. The oxygen in the atmosphere feeding the fire may be reduced to a low enough percentage (15% or lower) to cause the fire to be reduced to a glow. The officer must realize that not only are products of combustion altered by the reduction of oxygen, but so too is the burning rate. It should be noted that to intensify the fire in the wood stove, the draft should be opened. The process is the same within a structure.



The process described by the examples of the wood stove is similar to that in a structure fire, and may pass through four stages from a free burning state in the early stage to that of a self-extinguishing stage. Fire service authorities have suggested that the four stages depend on the amount of oxygen in the stmposhere.

Stage 1 - 21% - Free burning
Stage 2 - 17% - Reduced burning
Stage 3 - 15% - Smoldering
Stage 4 - Below 15% - Process continues toward self-extinguishment

It should also be noted here that as with wood stoves, to open the structure at lower levels will intensify the fire, perhaps violently. THEREFORE, HOSE LINES MUST BE IN POSITION, WITH WATER TO THE NOZZLE BEFORE VENTING OPERATIONS ARE STARTED.

All fire personnel must be familiar with the burning process and the violent results that may occur from improper opening procedures. Where a fire has been burning for some time in a closed building, with insufficient oxygen for complete combustion, the carbon monoxide collects and has a tendency to stifle the flames. Under such conditions, as soon as an opening is made into the building, fresh air and oxygen mixes with the carbon monoxide. The mixture formed is an explosive one, and the heat of the fire can cause an explosion known as a BACKDRAFT (Page 46). Whenever size-up indicates smoke with little or no flame visible, the officer would be well advised to assume backdraft conditions exist, and act accordingly. Suggestions for remedying this condition will be discussed later.

FIRE BEHAVIOR AND TRAVEL

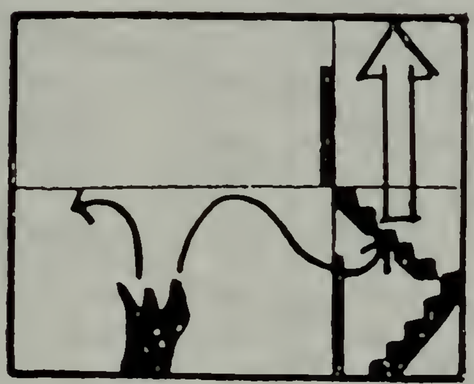
It is particularly important for a fire officer to understand and predict, from smoke conditions showing externally, something about fire location and avenues that may provide for horizontal and vertical extension. In order to perform ventilation effectively, he must consider how heat, smoke, and gases are transmitted through a structure. Although the three methods of heat transfer, conduction, convection, and radiation must all be understood for proper analysis of over-all fireground management, convection is most important for the explanation of travel of smoke and gases.

CONVECTION

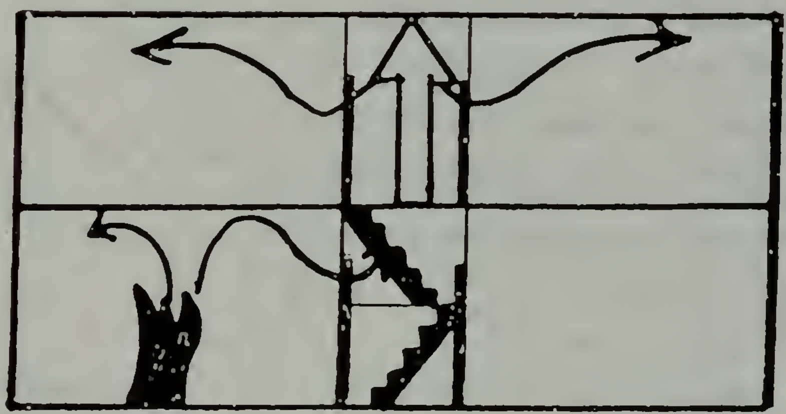
The theory of convection states that gases, when heated, expand and become lighter than air, causing them to rise. It is this physical property of gases that results in smoke seeking out and finding the vertical channels in a structure, rising to the top. Seeking the path of least resistance, it is convection that causes smoke to appear at upper levels upon size-up. To further explain fire travel, as well as emphasize the need for ventilation, every firefighter must understand mushrooming.

MUSHROOMING

Heat and smoke will travel up through vertical shafts such as elevator shafts and stairwells without entering any of the intermediate floors, until they meet with construction which interupts their progress, and acts as an obstruction. Such obstruction of their travel creates a condition called mushrooming. Instead of moving upward, the heat and smoke now



Smoke will find vertical shafts like this stairway and travel to upper levels



Once at upper levels with further travel obstructed, smoke will travel laterally and begin to bank down throughout the structure

begins to bank downward and spread laterally and will, in a short time involve all of the structure in fire. Therefore, the prompt venting of the structure at the point that will draw this heat and smoke up and out of the building will oftentimes result in the saving of lives and property, not to mention the untold punishment to firefighters during interior attack.

PRE-PLANNING AND IN-SERVICE INSPECTIONS

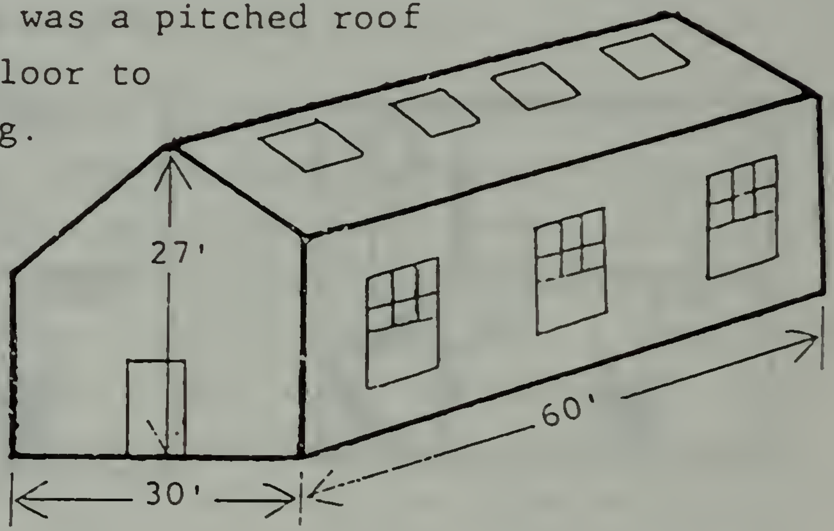
Because fire is transmitted through a building via vertical and horizontal channels, pre-planning becomes a very useful tool for fireground operations. Ventilation can become less of a problem if decisions are based on a knowledge of internal channels, and rooftop operation becomes less risky if skylights, hatches, and other openings are discovered and analyzed before the fire.

It should also be emphasized at this point that inspection activities can also serve to reduce fire damage, when, during inspections, the building is looked at from the perspective of fire spread. Smoke doors, fire doors, and other construction features installed for the purpose of obstructing fire travel are often found blocked open, damaged, removed, or otherwise ineffective. Correction of these violations may save immeasureable damage, even injury or loss of life, if restored to the condition for which they were installed.

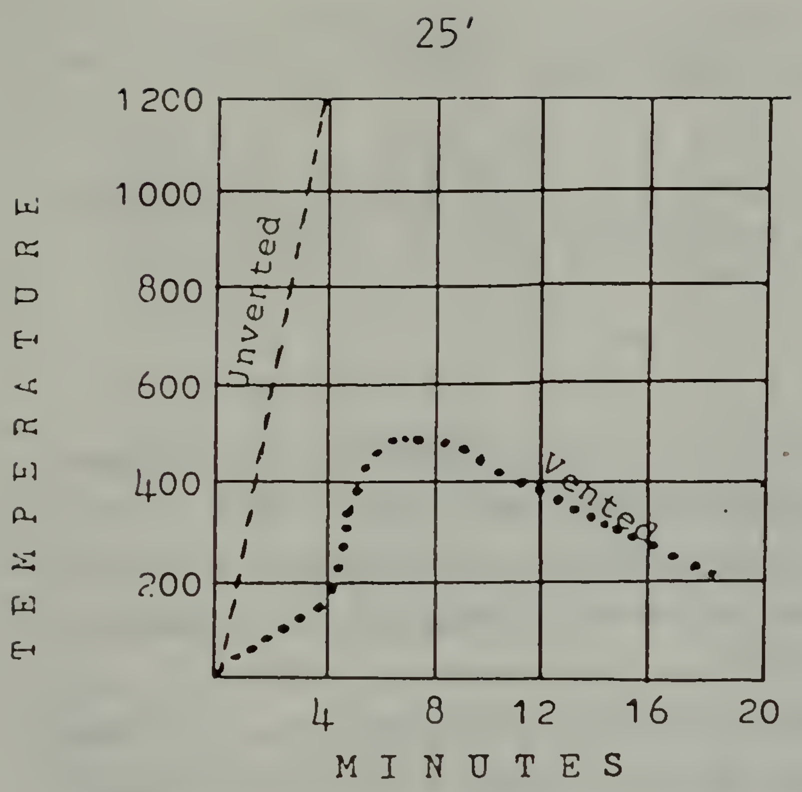
THE NEED TO VENTILATE

To further emphasize the need for ventilation mention should be made of tests conducted in England to support the concept of auto-roof vents. The building used was a pitched roof structure, unobstructed from floor to ridge pole, 30' wide X 60' long. Height from the floor to ridge was 25'. Heat recording devices were installed at three levels within the building:

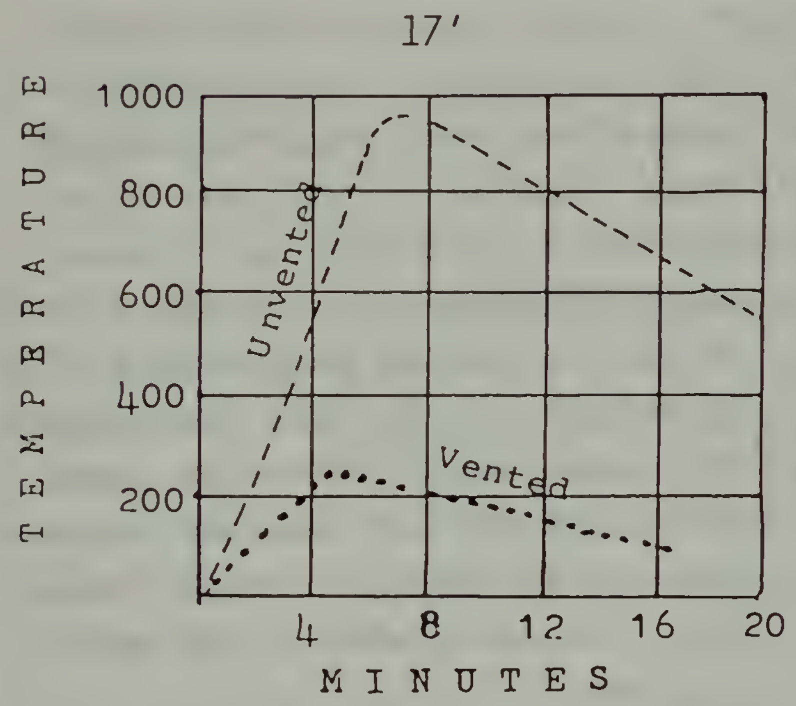
5' above the floor
17' above the floor
25' at the ridge



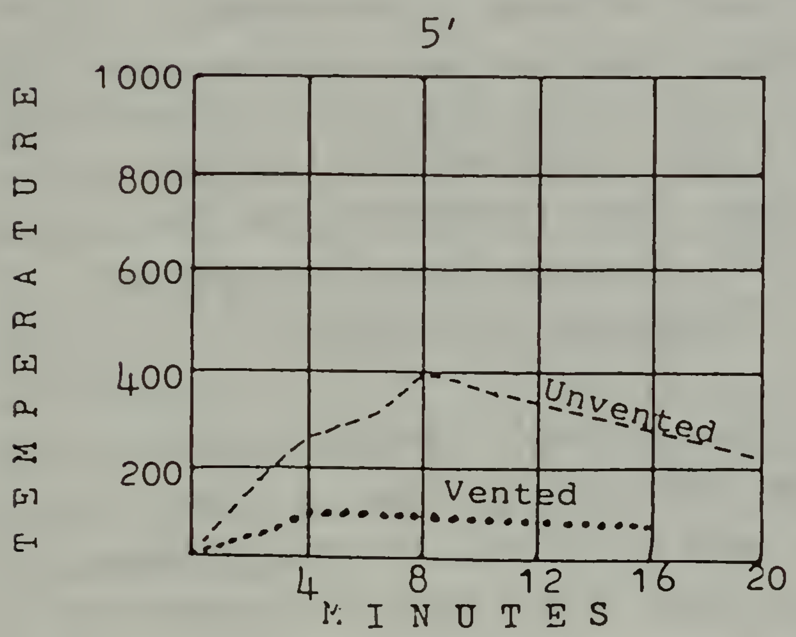
Building construction included four 4' X 4' self opening venting devices on each side of the roof. The vents provided considerably more venting area than is usually accomplished on the fireground, but demonstrated the value of ventilation.



This graph shows under unvented conditions, temperatures in excess of 1200 were reached at the ridge line in about 4 minutes. However, under vented conditions maximum temperature at the ridge line was only slightly above 500.



This graph shows the significant difference in temperature between a vented and unvented fire. At the 17 foot level, a maximum temperature of 950 was recorded under unvented conditions, while with venting the temperature only reached a very moderate 250.



The time temperature curve at the 5' level is indicative of conditions facing firefighters trying to make the seat of the fire. Assuming temperatures in the area of 150 and above as being untenable, it can be seen from the curve that such conditions would be present for the duration of the test fire under unvented condition. However, in the vented fire, the floor temperature never exceeded a tolerable 90 degrees.

Test conditions: Two fires were conducted. For each fire the fire load was identical, and recordings were taken from the heat sensitive devices at equal times into the fire. The principal difference between the two fires was that one fire remained UNVENTED, and the other fire was VENTED via normal operation of roof vents.

WHEN TO VENT

Perhaps 90% or more of the building fires fire departments respond to involve simply a 1½" line on a minor kitchen fire, rubbish, or mattress where extinguishment is accomplished and ventilation is performed either simultaneously or after extinguishment. However, upon arrival at a structure fire during the advanced stages of fire, heat conditions may prevent advancing of interior lines to the seat of the fire, particularly to upper floors. Many firefighters have experienced an incident of punishment trying to advance an attack line to the second or third floor, heat burning the ears outside the facepiece, until topside ventilation was performed, visibility improved and the atmosphere becomae more tenable. It is this type of experience that teaches firefighters not only the value of ventlation, but that in this type of condition, ventilation should be performed ahead of extinguishment. Delay in venting will result not only in excessive punishment to firefighters, but also contribute to ineffective hit or miss firefighting, sometimes called the promiscuous directing of streams into smoke. The WHEN of ventilation may vary, according to the stage of the fire on arrival, but in the case of buildup of smoke conditions on arrival, venting should, in most cases, be performed ahead of extinguishment.

> CAUTION: Lines must be in position with water to the nozzle before openings are made at lower levels.

Looking at conditions that dictate prompt ventilation, further support for the need for venting under these conditions can be provided by looking beyond the initial mushroom stage to a point in time where there may be either a Flashover or Backdraft

FLASHOVER. As fire progresses and time elapses, heat is transferred from the fire source to other parts of the room or area involved. As the ceiling and upper walls heat up, radiation feedback gradually heats up the contents until their ignition temperature is reached and simultaneous ignition occurs. Such ignition is called FLASHOVER.

The Officer-in-charge will have to consider that the time of flashover will depend on a number of factors, some of which include:

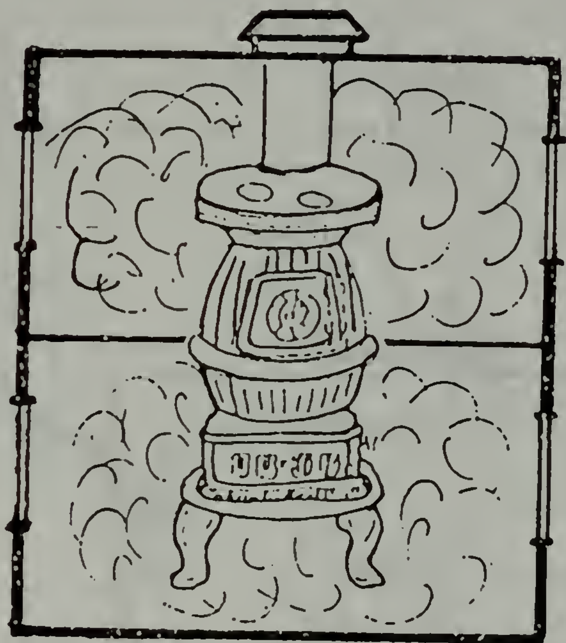
- Type of fire load
- Arrangement of fire load
- Amount of fire load in relation to room volume
- Surface area of fire load
- Fire conditions
- Amount of ventilation

Coordination of the venting operations, as it relates to fire control, advancement of attack lines, and the reduction of the possibility of flashover, must be addressed by the OIC.

BACKDRAFT. A phenomena deserving the concern and respect of every firefighter and officer is the Backdraft. Concern is rightly deserved because not only can the sometimes unsuspecting conditions create a violent release of energy that can injure or kill, but detectable warnings are not always obvious.

Conditions

During the first stages of the combustion process an adequate supply of oxygen allows for the flammable gases of the burning material to burn freely. If, however, there is insufficient oxygen, as in the later stages of fire in a closed building or area thereof, unburned gases may collect within. As described in the earlier part of this section, the burn process and gaseous behavior within a structure is similar in nature to the process within a wood burning stove. If the damper and other openings of the stove remain closed, the fire will not burn freely, but regress toward smoldering as products of combustion continue to build up within. One of the more prevalent gases under such conditions, carbon monoxide, may be present in abundant quantities, and within explosive range.



Warnings

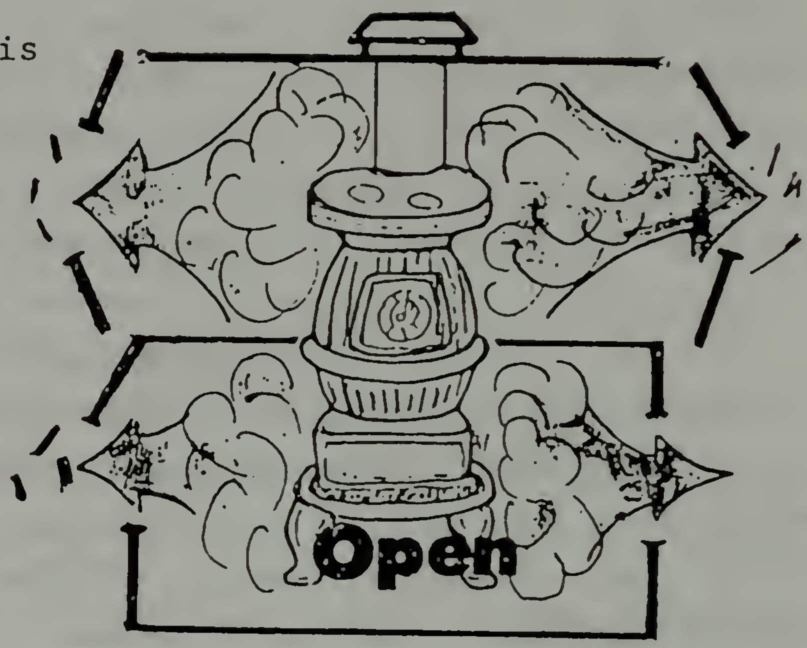
Visible factors that may indicate Backdraft conditions should be familiar to every officer for quick recognition.

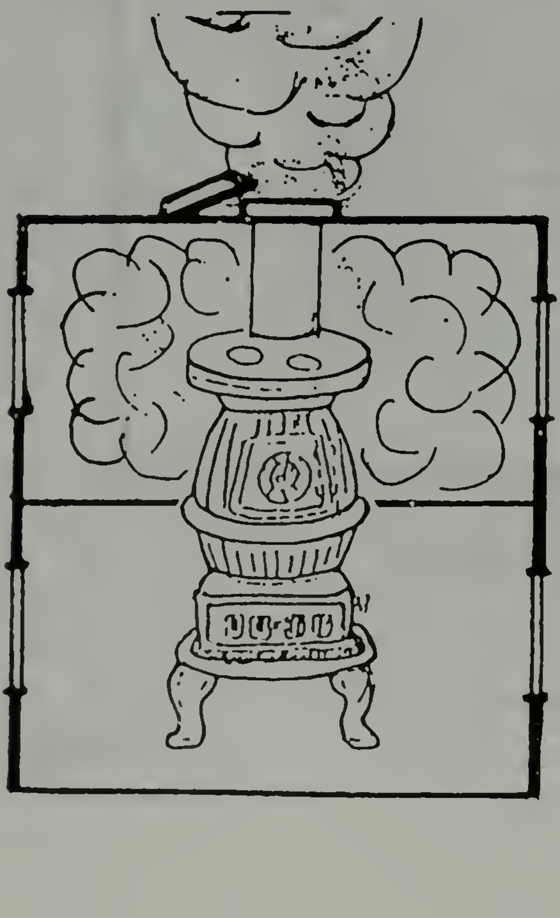
A. Obvious factors that indicate an oxygen deficient atmosphere
   1. Smoke showing, sometimes appearing to be "pushing" out under pressure.
   2. Little or no flame visible.

B. Evidence that fire is in its third or fourth stage
   1. Windows showing evidence, by discoloration and perhaps cracks, of heat build-up.
   2. Heat obvious within evolving smoke.

Possibilities

If the draft door of the stove is opened first, after a build-up has occurred, the sudden flow of fresh air and oxygen through this lower level opening into the chamber, may create a rapid increase in the intensity of the fire. In the case of a building, where carbon monoxide has built up to within explosive limits, the result of lower level opening(s) may cause a Backdraft. The energy released by a Backdraft can have the force to blow out walls





Precautions

How a fire structure is treated, therefore, relative to initial openings, should correspond to how we treat the adjustments on a wood burning stove to control the intensity of fire within. To relieve the conditions, the contaminants, possibly explosive products of combustion, should be exhausted from the building via topside opening or openings. Once adequate topside venting has been accomplished, openings may be made at lower levels for entry and attack.

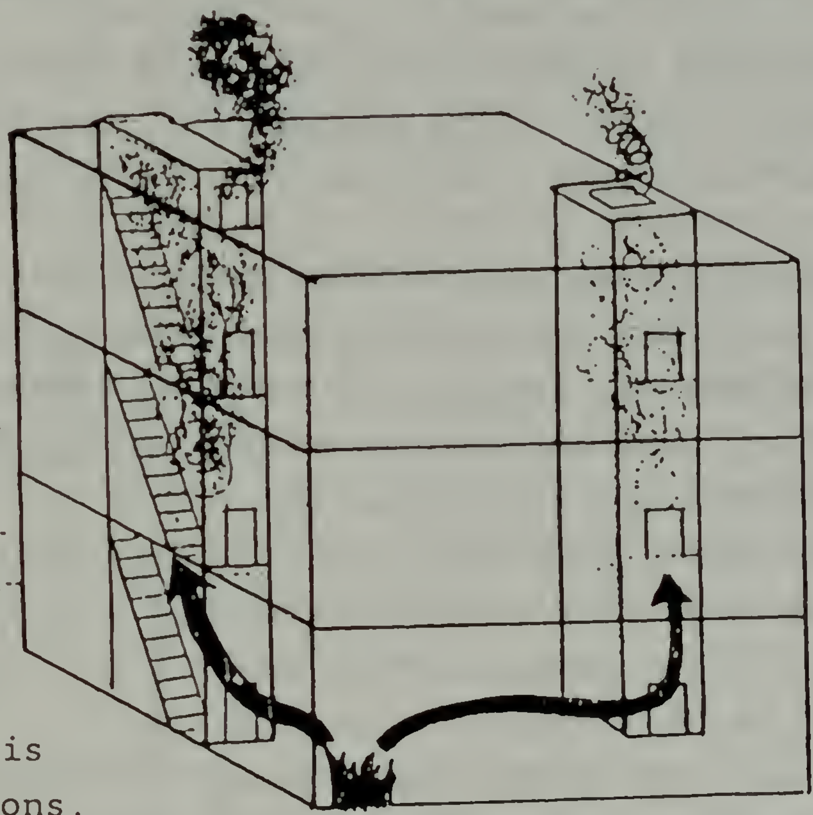
in the case of smaller structures with pitched roof, it will be difficult to create the chimney effect for good topside venting. As an alternative, the officer may opt to take out the upper portion of windows with long pike pole.
CHARGED LINE(S) MUST BE READY TO REACT TO RAPIDLY CHANGING CONDITIONS.

WHAT TYPE OF VENTILATION?

Not only must the timing of ventilation be appropriate, but also the method. It is recognized within the fire service that there are two types of ventilation used for structure fires: Top, or Vertical ventilation, and Side or Horizontal ventilation. Generally, venting an involved structure will follow one or both of these two types.

VERTICAL

Ventilation will be accomplished most effectively and thereby have a more positive impact on other firefighting operations when construction features allow for the venting path to follow the direction of travel nature intended - upward. Remembering that heated gases expand, become lighter than air, and rise, it therefore must follow that the path of least resistance to the outside will be as close as possible to straight up.



If a chimney could be placed directly over the fire, venting would be most effective. Realistically, the best we can do is take advantage of existing vertical channels, such as stairways and elevator shafts.

As previously mentioned, adequate size up is perhaps the most important building block on which an officer can base his decisions for tactical evolutions. Ventilation is a prime example of this statement. The time taken to determine the location and extent of the fire, together with the officer's knowledge of building construction and fire travel, will provide the When, Where, and How of ventilation. Once size-up of fire conditions and construction determines that vertical venting will be the most practical, the officer must consider the planned

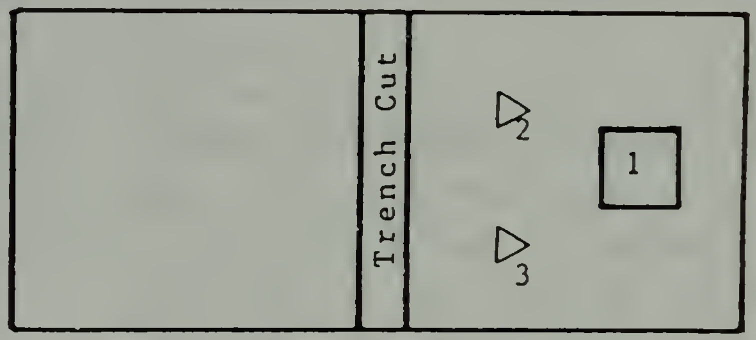
and systematic part of the operation.

A vertical shaft must be selected to be used as the primary internal chimney. Consideration will have to be given to vertical shafts that will draw heat, smoke, and gases most effectively. As shown in the sketch on the previous page, the stairways, being closer to the point of origin, has more buildup of products of combustion and may be the most effective channel for ventilation. One channel should be selected for opening, although fire conditions may warrant use of more than one shaft. Crews on the roof should review their basic training when selecting a location for initial opening.

NOTE: An exception to normal venting procedures may have to be used when a stairway is being used by occupants as a means of egress. In such cases, in order to leave the stairs tenable, another channel may have to be used for venting.

THE TRENCH CUT. The trench cut, by definition, is a roof opening that runs the full distance between two exterior walls, or other fire stops, dividing a portion of the roof that is burning from a portion that is not burning. This type of opening has proven effective at fires involving cocklofts or "Taxpayer" type structures, as well as large area multiple dwellings, and others. The purpose of the cut is not to replace the primary cut, but more as a defensive action to limit or prevent extension of fire in the cockloft.

In the accompanying sketch, opening "1" is the primary cut. Once fire is found in the cockloft, holes "2" and "3" are cut as exploratory holes to assist in proper placement of the trench cut. If no fire is found in holes 2 and 3, the trench cut is carried out, beyond the exploratory holes and in the suspected path of fire travel. If, however, fire was found in the original exploratory cuts, other exploratory cuts will have to be made until a point beyond fire extension is reached. As with all fireground operations, coordination is essential. Interior attack crews, as conditions permit, should be pulling ceilings to expose fire for extinguishment, and progress, both interior and topside, must be communicated to the Command Post.



It should be remembered that the trench cut does not replace prompt overhead ventilation, but rather is a defensive tactic that, if properly carried out, can reduce property loss and reduce knockdown time.

Premature or Remote Ventilation

It must be realized by every fire officer that premature opening of the building at lower levels, or top venting remote from the fire, can contribute to the rapid spread of fire to otherwise unexposed areas within the building. A contributing factor to this kind of ventilation (or in some instances, lack of) is taking action before proper size-up is accomplished, or before water is ready in hose lines. Venting, under these circumstances, is done without adequate consideration on one or all of the following:

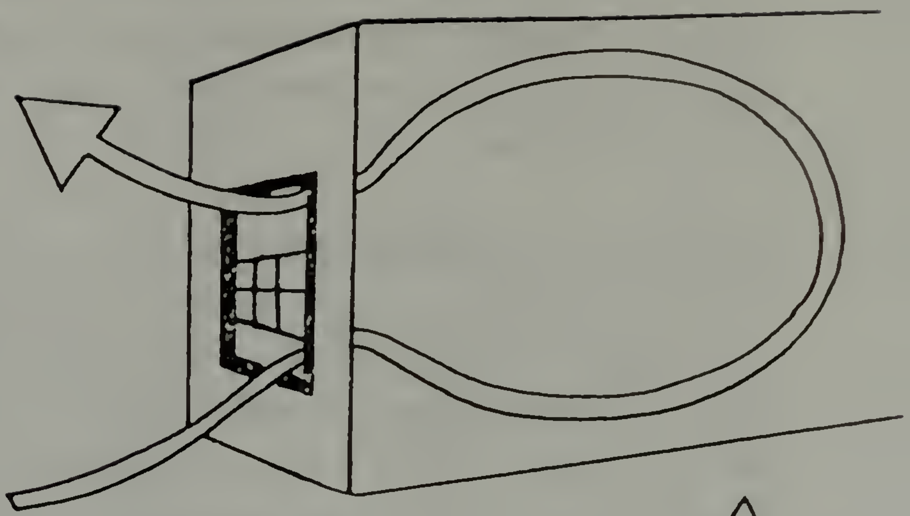
1. Extent and location of the fire
2. Nature of building construction and contents
3. Exposures
4. Readiness of firefighting forces

HORIZONTAL

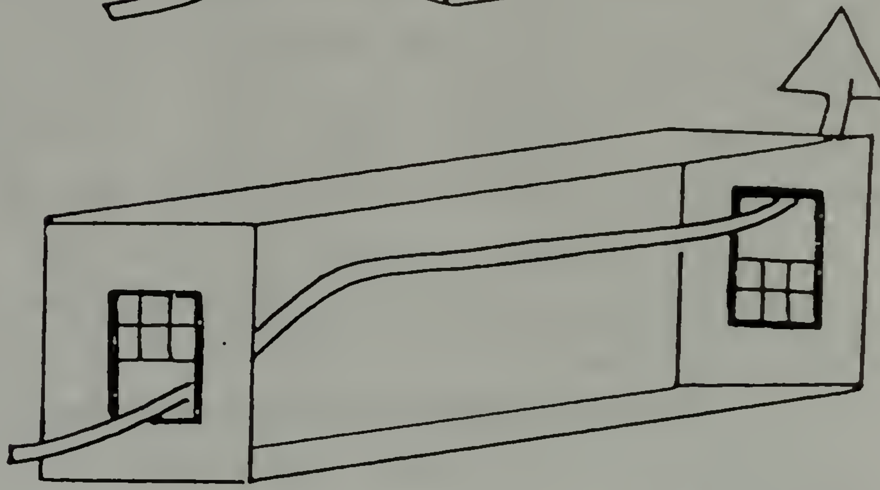
In theory and practice, the proper procedure for venting a structure is to open first above the fire, thus releasing the build-up of heat, smoke,and gases to the outside vertically. However, the experienced officer is quick to recognize that fire or construction factors may restrict or prohibit vertical venting. In such cases, consideration should again be given to limiting openings in number and location to those that will restrict fire and smoke travel as little as possible to unexposed areas. When considering horizontal ventilation, particular attention must be given to prevailing wind direction. Whenever possible, smoke, heat, and gases should be channeled out the leeward side. An adverse breeze, however slight, will obstruct cross ventilation to a noticeable degree.

Window venting, using cross currents and convection currents will be effective for most fires caught in the early stages. The area involved will also determine the scale of the horizontal process. One room ventilation involves, ideally, dropping the top portion of windows down 2/3, raising the bottom up 1/3, allowing fresh air to come in the botton, circulating via convection currents, forcing warm, contaminated air out the upper portion. Storm windows may make this

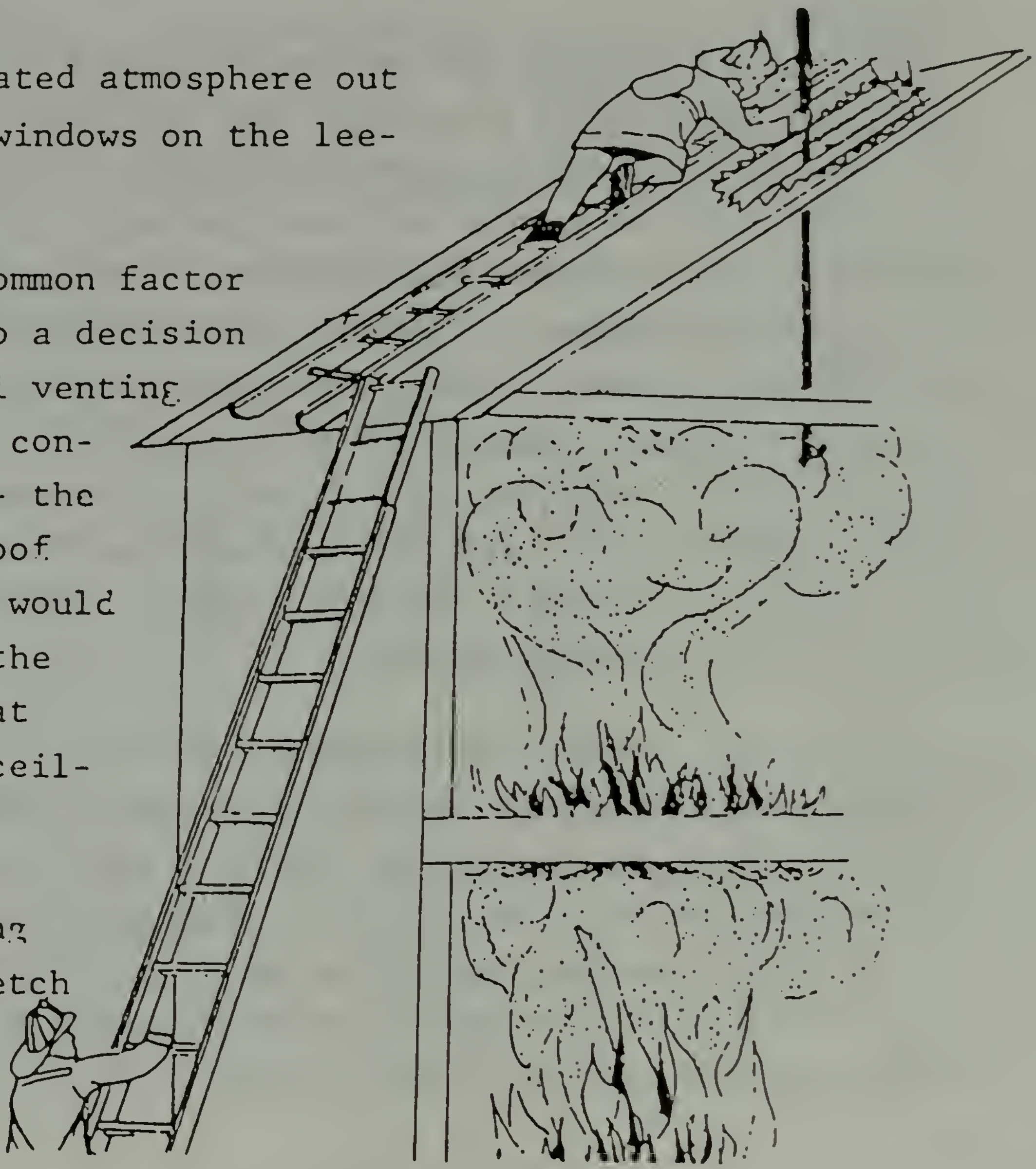
difficult or impossible unless first removed. It should also be remembered that screens provide as much as 2/3rds obstruction within the opening and should be removed to provide a clear channel to the outside.



In the case of large, unobstructed areas, windows should be opened first down from the top on the leeward side, and up from the bottom on the windward side. Again, this takes advantage of the elements and convection forces to force the contaminated atmosphere out the upper part of windows on the leeward side.



Perhaps the most common factor that contributes to a decision favoring horizontal venting over vertical is a construction feature - the pitched roof. A roof opening most often would be separated from the heated atmosphere at lower levels by a ceiling. Seldom is it practical to open the roof and ceiling as shown in the sketch for a routine , one room fire.



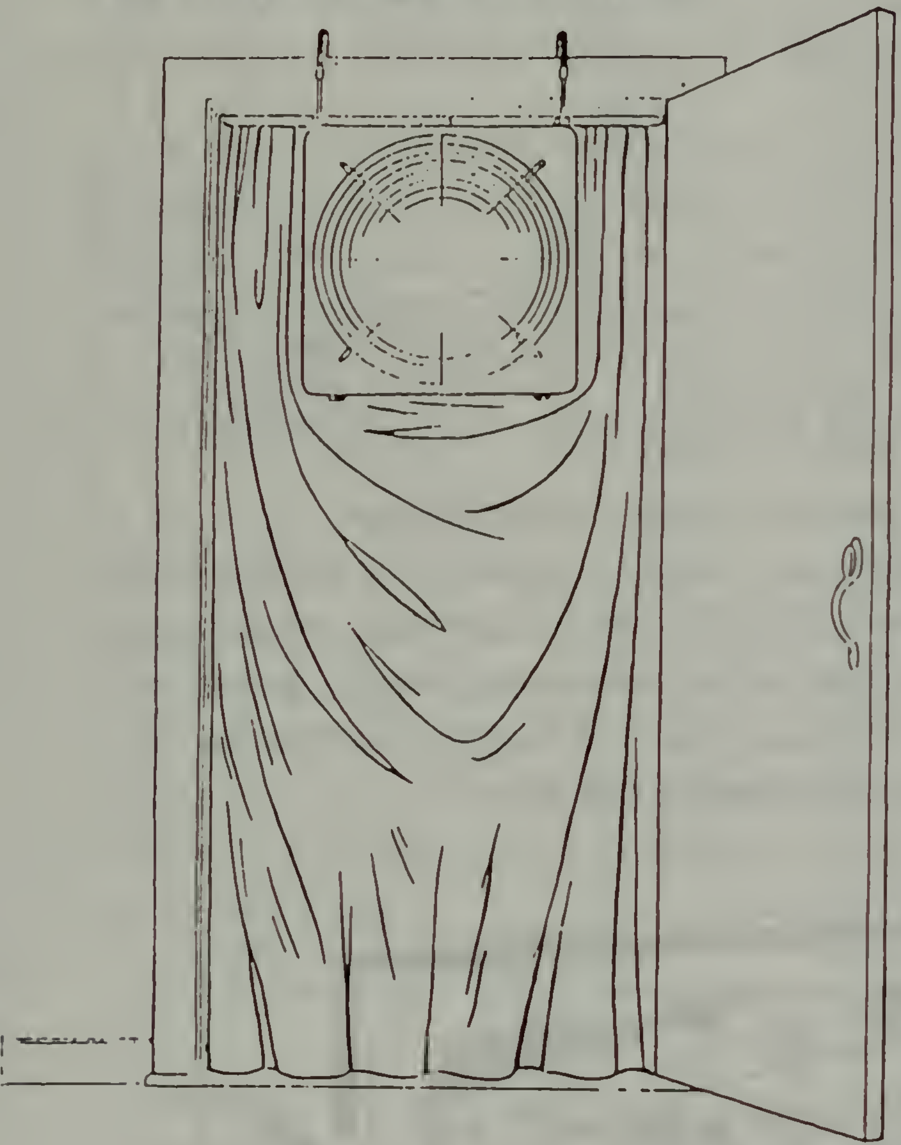
Courtesy of IFSTA Manual 107

If, however, fire is found or suspected in the attic, or if a partition or extensive fire in balloon frame construction is encountered, conditions will most often require opening the pitched roof.

MECHANICAL VENTILATION

Most, if not all fire departments today are using mechanical smoke ejectors to assist with the natural flow of contaminants during some ventilation operations. Smoke ejectors can not only augment and supplement natural flow of ventilation, but can insure closer control of ventilation. Manufacturer's operating instructions should be reviewed regarding the capabilities of such equipment, but fire and heat behavior will always dictate that ejectors be placed as high as possible in the area, to be most effective in removing smoke.

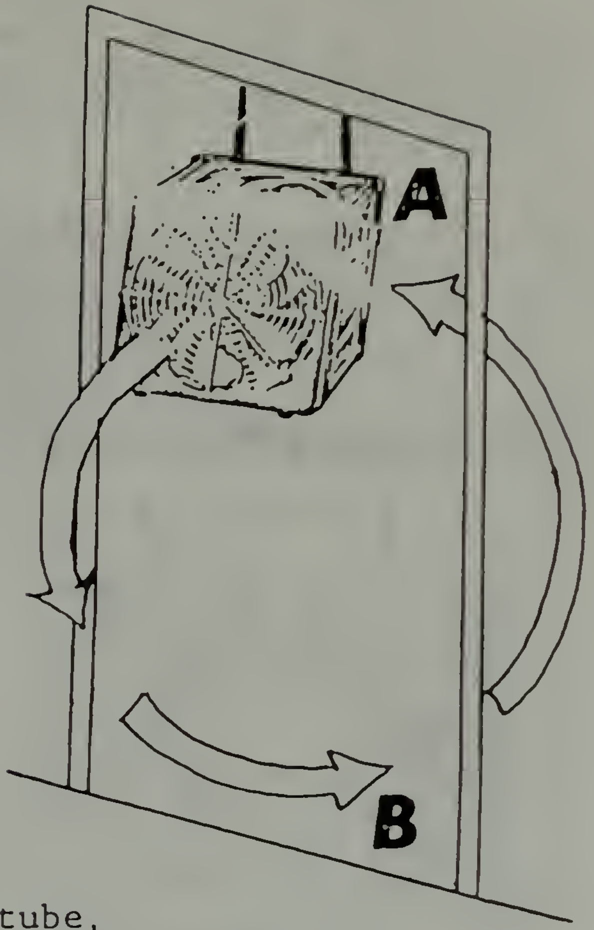
Door Casing Placement



Two additional points should be briefly mentioned regarding the effective use of ejectors. First, when venting via a window, air flow can be increased by removing not only drapes and curtains, but also screens.

Secondly, the principle of churning must be understood, recognized, and eliminated in order for the ejector to function properly. This principle, simply stated, suggests that if air flows in the path of least resistance, an ejector placed in a doorway, rather than pull smoke from across the room, will instead simply circulate air only in the immediate area of the doorway as shown on the following page.

In order to achieve greatest pulling power from the equipment to the other side of the room or area, the spaces between points "A" and "B" should be obstructed with a canvas door curtain or salvage cover as shown in the previous diagram.



THE FOG STREAM AS AN EJECTOR

The velocity of the fog stream causes turbulence around the stream which can, when properly directed, be used effectively as a smoke ejector. Just as we take advantage of the Venturi Principle when using water velocity, coupled with an eductor, to pick up foam concentrate via a pick up tube, so the fog stream will channel smoke. It is interesting to note that the common size smoke ejector is generally advertised as capable of moving approximately 12,000 cubic feet per minute of air and contaminants. A 1½" nozzle, with adequate nozzle pressure for a 90 to 100 GPM discharge, using a 30 to 60 degree pattern, is

USING FOG TO EXPEL SMOKE AND GAS

Courtesy of IFSTA Manual 107

capable of moving 20,000 CFM. This method can be established once knockdown has been accomplished, and before more structured ventilation can be set up.

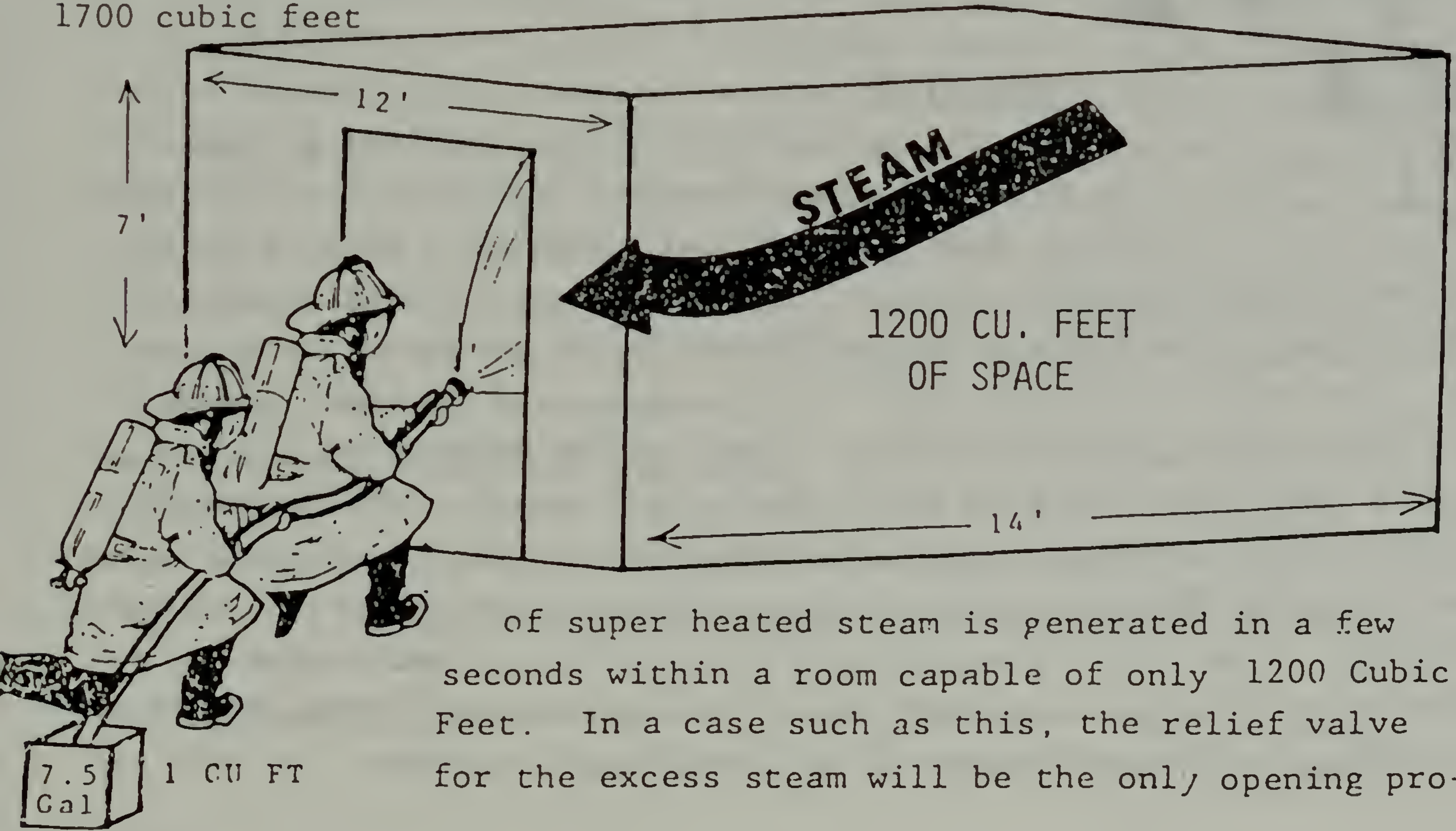
NOTE: It must be remembered that any place air can travel, fire can follow. Currents should not be established for the flow of fresh air in the fire area until fire is completely extinguished, or it has been determined that such air flow will not cause additional extension.

FOG CONVERSION AS IT AFFECTS VENTILATION

Despite the technological and scientific advancements in other fields, effective firefighting still depends on firefighters advancing a hose line into a hostile environment and making an interior attack. It is this interior attack that, due to its complexity, must be understood, particularly from the aspect of ventilation needs.

It has been some time now since we learned and adapted to the concept of using water in finely divided particles for heat absorption, conversion, and thereby extinguishment of fires in confined areas. However, it must be remembered, particularly in a discussion of ventilation principles, that use of the fog nozzle and stream generation, coordination must be accomplished between application and ventilation.

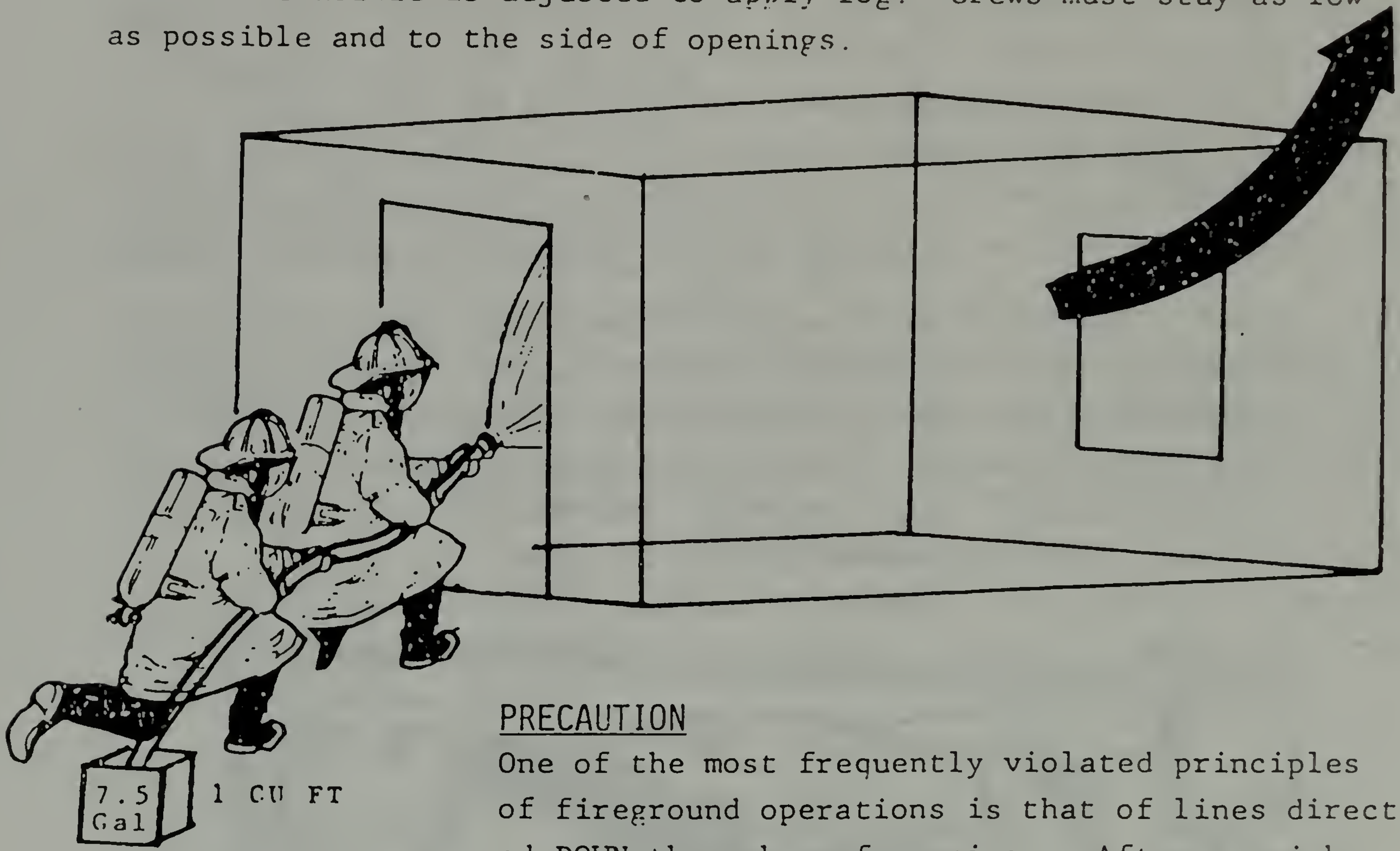
The principle benefit of water as an extinguishing agent is not only its availability, but its heat absorbing qualities. During the process of being converted from a liquid at 60 F, through the boiling point, into a gaseous state of steam, one pound of water will absorb in access of 1100 BTUs. When one cubic foot of water (7.5 gals) is converted into steam, the expansion rate is 1700 times greater. A problem, therefore, may suddenly arise when, as in the sketch below, 1700 cubic feet



of super heated steam is generated in a few seconds within a room capable of only 1200 Cubic Feet. In a case such as this, the relief valve for the excess steam will be the only opening pro-

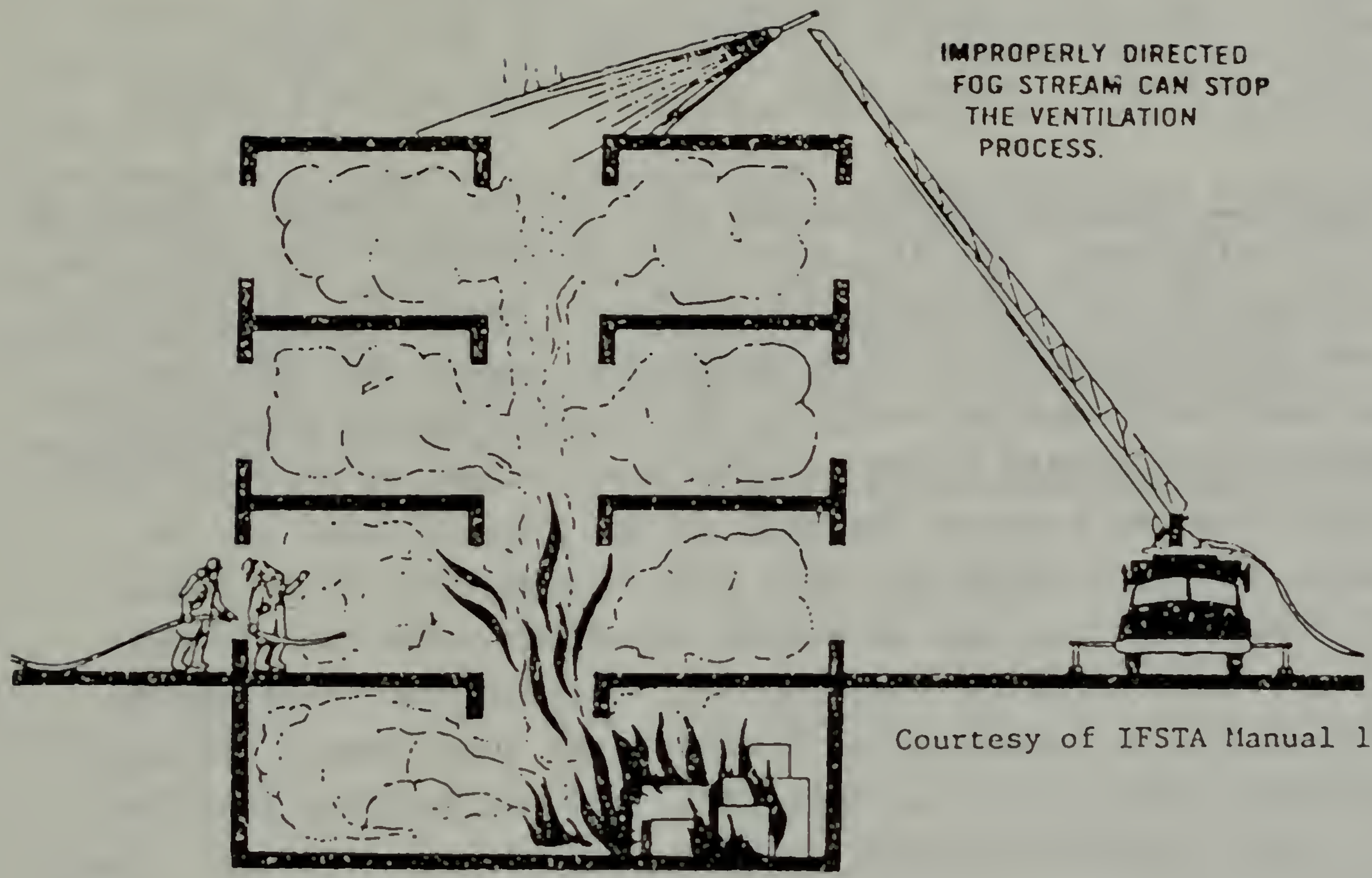
vided in the room, through the doorway. Unfortunately, that opening may contain the one or more firefighters engaged in extinguishing activities, and serious injury may result.

Ventilation should be performed ahead of the fog nozzle in confined areas to allow the rapidly expanding steam to vent via opening(s) other than the one used for application. Understandably, manpower and other restrictions may sometimes prevent the luxury of a venting crew coordinating it efforts with the attack crew. Under such restrictions, the attack crew should keep in mind that a straight stream on the hot glass will break the glass, providing at least limited venting before the nozzle is adjusted to apply fog. Crews must stay as low as possible and to the side of openings.



PRECAUTION

One of the most frequently violated principles of fireground operations is that of lines directed DOWN through roof openings. After a quick review of fire and heat behavior, one recognizes that the natural flow of heated products of combustion within a structure is UP and OUT. Too often, however, after considerable hard work and punishment on the part of firefighters to set up the natural flow, someone makes a decision to use an aerial ladder as shown in the following sketch. Not only does such direction of a heavy stream disrupt normal channeling of fire up and out, but prohibits otherwise effective firefighting. Even a 1½" line can completely disrupt ventilation and force heat and smoke back down into the levels below, spreading fire and adding to the punishment of any firefighters inside.



Courtesy of IFSTA Manual 107

SUMMARY - ADVANTAGES

To summarize the importance of ventilation as it affects fireground management, every fire officer should consider the following list of advantages that can be accomplished through prompt and effective ventilation.

1. SAVING OF LIFE. As long as heat, smoke, and gases are allowed to remain in a structure, occupants in the building and firefighters in the performance of their duties are subjected to asphyxia or carbon monoxide poisoning. Poor visibility complicates this problem, making it difficult for occupants to find safe exit to the outside, and delaying firefighters reaching trapped victims. Ventilation hastens and simplifies the rescue of trapped persons in a building or area. It safeguards the firefighter's own task in rescue and fire attack, and facilitates search for the removal of those who might be in danger.

2. LESSENS THE DANGER TO EXPOSURES. Good ventilation helps to minimize the exposure to floors above the fire and to adjacent buildings. By clearing the path for firefighters, it permits them to cut off fire that may otherwise threaten other property and possibly lives.

3. SPEEDS ATTACK. Removing heat, smoke, and gases permits firefighters to locate the seat of the fire promptly and get lines

into position to effect extinguishment. Ventilation, by improving visibility, enables firefighters to more quickly determine the path of fire travel so that they can more easily control it.

4. SIMPLIFIES THE FIREFIGHTER'S JOB. It not only affords safeguards for the firefighters, but it lessens the punishment they must take in carrying out the task assigned to them. Therefore, it reduces fear and improves morale. Good ventilation saves the fire department hard cold cash be reducing the injury time to members.

5. PREVENTS UNNECESSARY WATER DAMAGE. Every experienced firefighter knows that when he gets to the seat of the fire quickly and extinguishes it, he reduces not only fire damage, but water damage as well. Firefighting can be easier sometimes from the sidewalk, but it must be remembered that the most ineffective firefighting is the promiscuous directing of hose streams into smoke. Streams directed into smoke, for the most part, are not hitting the fire directly, and therefore simply contributing to water damage. Ventilation provides tenable conditions that may make it possible to locate, surround, confine, and extinguish the fire with a minimum amount of water being used.

6. PREVENTS BACKDRAFT. A condition feared by firefighters is the unexpected and often unexplained explosion of pent-up heat and combustible gases in a fire building. Frequently on explosion may touch off a chain of explosions involving accumulations of explosive gases in pockets or concealed spaces in the building. The degree and intensity of the explosion or backdraft depends usually upon the area filled with the mixture of gases and the volume of fresh air coming in contact with it. Drawing these explosive gases up and out of the building via topside ventilation reduces the danger of explosion.

7. PREVENTS MUSHROOMING. Efficient ventilation reduces the possibility of fire spreading horizontally at the top level of the structure. Properly placed openings above the fire will create a channel or draft up which fire and heat will follow and be exhausted from the building. Such ventilation can often be as effective in controlling fire as the placement of multiple hose lines.

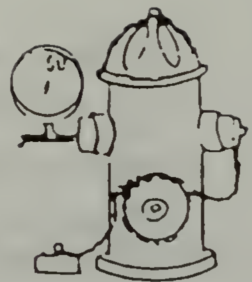
8. REDUCES SMOKE DAMAGE. Prompt and efficient ventilation will reduce the smoke damage to other floors or sections of the fire building.

9. <u>ENABLES PROMPT AND EFFICIENT SALVAGE OPERATIONS</u>. The faster the attack upon the fire and the faster it is extinguished, the less need there will be for lengthy overhaul, and the greater the opportunity for effective salvage.

10. <u>BUILDS PUBLIC RELATIONS</u>. The fire service is ever striving to improve its image. Since good venting practices result in good firefighting, it therefore must follow that public confidence in the fire service will increase. All departments benefit from another's good work.

FIREGROUND

WATER



SUPPLY

Initial fire control efforts must be based on a fast but sound size-up of conditions on arrival. This size-up will be based on the officer's ability to estimate fire flow requirements; fire flow that will produce a rate of water application capable of absorbing the heat being generated. When estimating the require-ed fire flow, the officer must consider not only the present conditions, but also future requirements due to the probabilities and possibilities of fire extension.

Before selecting and committing attack lines, the officer must consider where and how the fire flow will be obtained. The decision for a particular method of supplying water will be based on the volume required and the speed of delivery necessary. It is this moving of water from source to nozzle that constitutes <u>Fireground Water Supply</u>.

Water supply is another area of fireground management that can make or break the entire operation. This phase of firefighting is given so much weight by progressive fire departments that one officer is assigned to this task, under both emergency and non-emergency conditions. From the Officer-in-charge down to the pump operator, priority must be given to establishing adequate supply <u>early</u> into the fire. In order to establish and maintain an adequate supply, officers must have a thorough understanding of the principles of moving water.

An officer who is reviewing fireground water supply must first reassess his knowledge of the municipal water supply system. It is familiarilty with the municipal system that may well determine the strength of decisions affecting the outcome of a challenging fireground problem. It is therefore the responsibility of each

officer to be confident about not only his own knowledge, but also of the company's or companies' within his authority. Companies should be thoroughly familiar with main sizes, flows, and pressures in various parts of their district, as well as the location of hydrants in critical high value industrial, mercantile, or high rise areas where they are part of the first alarm response. Pre-planning and training should be inter-related, and sessions should be frequent enough to reenforce this knowledge to pump operators and officers.

Another subject area vital to water supply management, but not covered in depth in this text, is hydraulics. Since water supply is basically defined as moving water from the source to the fire, and since friction loss is the enemy of any such movement, it follows that operators and officers must have the ability to:

1. Mentally evaluate and compute hose layouts to determine if a particular layout will be hydraulically effective. Familiarity with the effective carrying capacity of the various hose sizes is essential.

   2½"..........300 GPM
   3"..........500 GPM
   4"..........1000 GPM
   5"..........1350 GPM

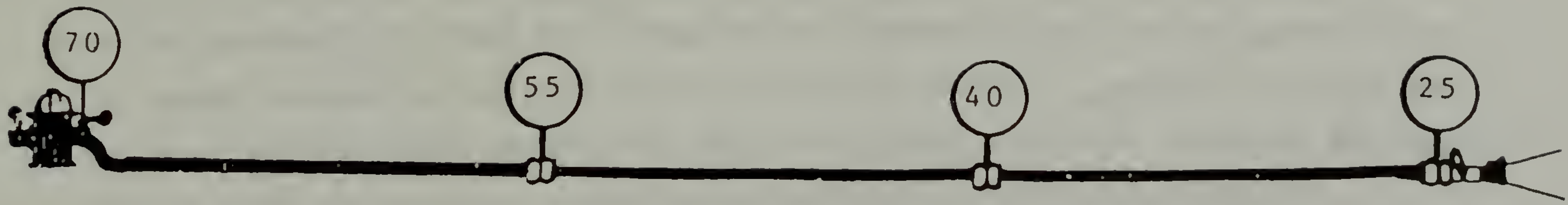
   NOTE: The above chart represents flows available at approximately 20 psi friction loss per 100'. It should also be recognized that the capacities may be exceeded, but with correspondingly greater friction loss.
2. Using a rule of thumb, calculate figures for discharge, friction loss, and engine pressures on which decisions can be based affecting fireground operations.

Further discussion relative to water supply will be based on the assumption that the reader has a knowledge of basic hydraulics.

WHY NOT HYDRANT LINES?

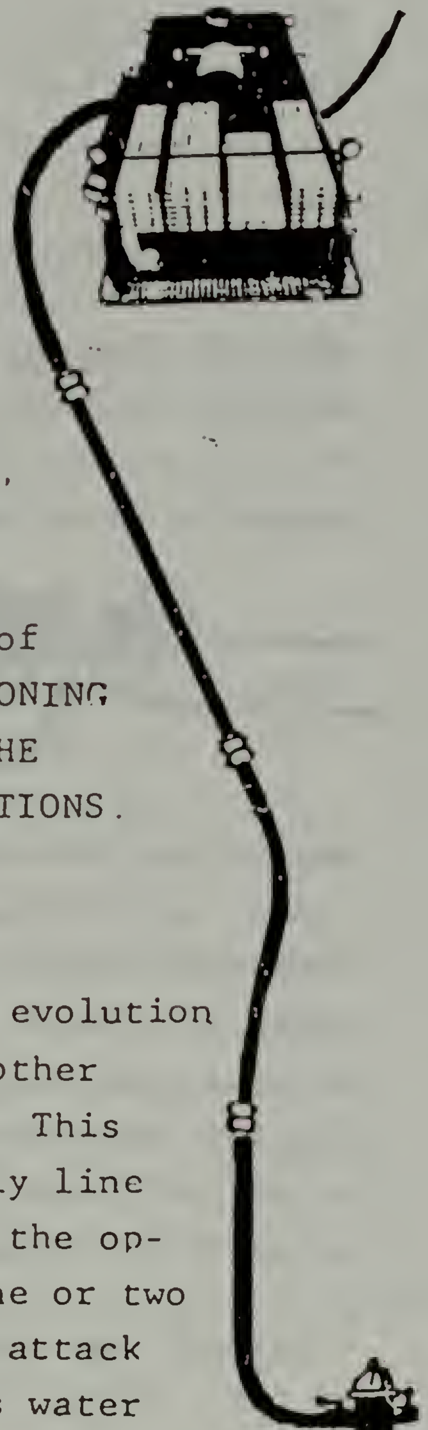
Most, if not all combination nozzles used in the fire service today, whether constant flow type or variable flow, require 100 psi nozzle pressure. This fact alone, make impractical, the running of hand lines directly off hydrants. A residual hydrant pressure of 70 psi would not be adequate to supply a 300' line, as indicated in the

diagram below.



Even if solid bore, straight tips are used, requiring 50 psi nozzle pressure, use of direct hydrant lines can still cause a a breakdown of effective water application.

The proper selection, placement, and application of fire streams are a critical factor in the success of any fireground operation. Since the nozzle must be supplied from a source that provides punch, from both the volume and pressure aspect, ALL LINES MUST BE PUMPER LINES.



Since pumper lines provide a means of regulating and maintaining effective flow application from nozzles, a rationale must follow that pumps must be supplied with adequate, strong water supply.

There are many different evolutions that will serve to provide support of engines in key positions. The type of evolution a department selects should be based on its apparatus response, manning, and supply sources. Each department must analyze, based on sound principles, how it can best provide adequate supply to take advantage of the capacity of pumpers in key tactical positions. INITIAL POSITIONING AND USE OF ENGINES MUST BE ADEQUATE TO ALLOW FOR THE BUILDING AND EXPANDING FOR FUTURE FIREGROUND OPERATIONS.

In-Line Pumping

Most fire departments are using an In-line pumping evolution for supply with fires in residential districts or other areas.where one or two room fires are encountered. This evolution involves the attack engine laying a supply line going in. When the engine is properly positioned, the operator places a hose clamp on the supply line as one or two preconnected attack lines are being advanced. The attack line(s) are charged and supplied from the apparatus water

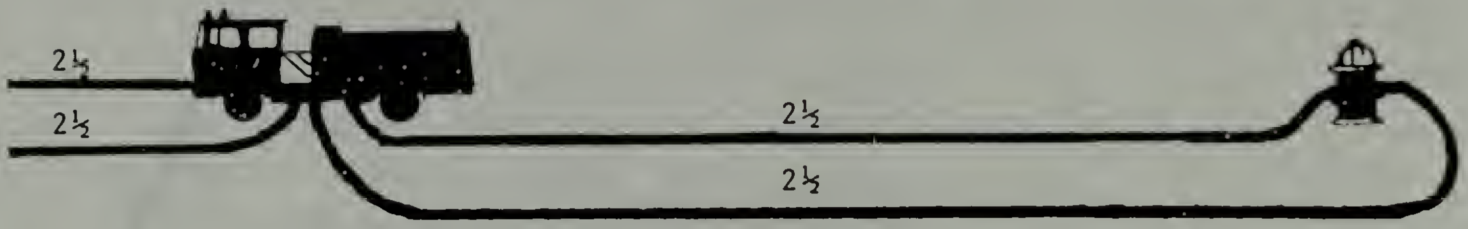
tank. The evolution is used for a quick attack on one or two room fires, with supply being converted from tank to hydrant before the tank is empty. Officers must be aware, when ordering this type of attack, of the limitations of the tank water supply, as well as the limitations of in-line hose layouts.

Consideration must be given to the loading of hose beds with the proper size hose in order to be flexible on the fireground with In-line pumping. As an example, a department that is using 2½" for supply lines may be limited to two 1½" discharge lines, or one 2½", whereas a 3" feed line allows the flexibility of perhaps two 1½" plus a 2½" back up line. Departments using large diameter hose for In-line pumping gain considerably more flexibility. Officers must remember, the larger the hose, the greater the flow.

For effectiveness, consideration must also be given to how feed lines are tied into the attack pumper. If a siamese is provided on the large suction manifold, single feed lines fed into the siamese will allow "building" by using the other side of the siamese and/or the auxiliary intake.

WHY NOT IN-LINE PUMPING FOR LARGE FIRES?

In-line pumping is most often as ineffective under major fire conditions as the hydrant line previously described. If a 1000 GPM pumper arrives at a fire scene where the officer suspects the



engine may eventually, if not immediately, supply multiple large lines, and elects to lay long dual lines or a single line down the street to feed apparatus, friction loss and limited carrying capacity may render the evolution ineffective, if not useless, unless a supply pump is used at the hydrant. The use of master streams at the end of such an In-line set up may not be possible. At this point, a fire department should look at its SOP's and ask, "Whose responsibility is it to establish a water supply"?

Providing the hydrant is capable of supplying the volume of water at the desired pressure for the two 2½" discharge lines run off the

pumper, the 1000 GPM pumper on the previous page is restricted to approximately 600 GPM capacity. Considering the effective carrying capacity of 2½" to be 300 GPM, this pump may not receive more than 600 GPM, therefore may not deliver more. A 1000 GPM pumper is then reduced by its hose layout to a 600 GPM pumper.

CAUTION

In order to eliminate any misconceptions on the part of operators and officers, a basic principle of carrying capacity should be reviewed at this point. The effective carrying capacity of a particular hose size or layout is by no means a guarantee when supplied by a hydrant. It must be remembered that the volume of supply will be determined first by the capability of the source. Although a 3" line has an efficient carrying capacity of 500 GPM, if the line is laid from a hydrant that is capable of only 300 GPM, the flow will never exceed 300 GPM, regardless of the hose diameter used for supply.

Low static hydrant pressure can also restrict supply, as discussed earlier. Even on a hydrant with a flow capability of 3000 GPM, if the static pressure is only 50 psi, flow for firefighting may be considerably less than the efficient carrying capacity of the hose used. Efficient carrying capacity flow figures are based on an average of 20 psi friction loss per 100', and can only be attained if source volume and pressure is adequate.

Example: With a 400' lay of 2½" hose, to obtain efficient carrying capacity, plus 20 psi residual at the pump, the source would require a residual of 100 psi. In most cases, the maximum flow that could be expected, with average hydrant pressures, using a 2½" feed line 400' long, would be approximately 200 GPM

Consideration must also be given to the importance of the operator's ability to read gauges and determine the amount of water available when pumps are connected to hydrants. Static pressure, for example, presents little indication of the true volume of water available from a hydrant. It is only by comparing the initial pressure reading with the residual pressure when water is discharged through the first line that determines the approximate amount of water available from a hydrar The pump operator, after connecting up and turning on the hydrant, should check the incoming Static Pressure coming into the suction

side of the pump before any water is discharged from the pump. Then, when the desired volume of water is being discharged from the first line, he should again check the suction gauge for the Residual Pressure. The difference in pressure between the initial Static Pressure and the Residual Pressure indicates the approximate volume of water available from the hydrant

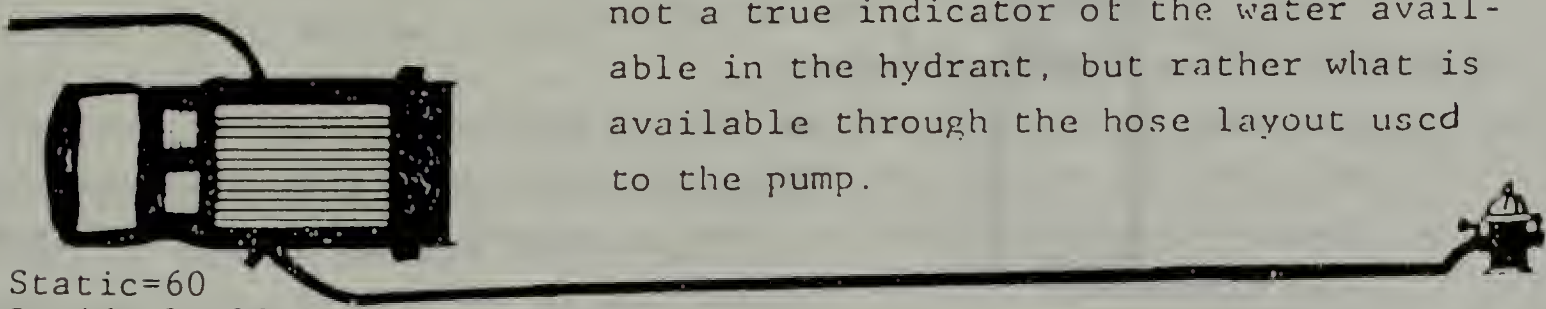
STATIC-RESIDUAL PRESSURE RULE

A. If the pressure drop from the initial Static Pressure to the flowing Residual Pressure at the pump is not more than 10%, the hydrant and incoming supply line(s) should supply THREE more streams of the same flow as the first line, for a total of four.
B. If the pressure drop from the initial Static Pressure to the flowing Residual Pressure at the pump is more than 10%, but not over 15%, the hydrant and incoming supply line(s) should supply TWO more streams of the same flow as the first line, for a total of three.
C. If the pressure drop from the initial Static Pressure to the flowing Residual Pressure at the pump is not over 25%, the hydrant and incoming supply line(s) should supply ONE more stream of the same flow as the first line, for a total of two.
D. If the pressure drop from the initial Static Pressure to the flowing Residual Pressure at the pump is over 25%, the hydrant and incoming supply line(s) will not supply another stream of the same flow as the first line.

In order to properly judge the flow potential of the water supply system using the Static-Residual Pressure Rule, the supply line(s) from the hydrant to the suction side of the pump must be large enough to keep the friction loss in the supply line to a bare minimum.

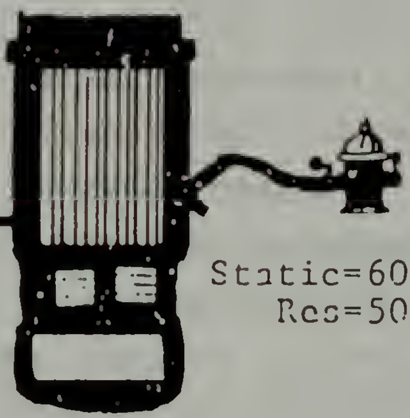
In those cases where a single supply line from the hydrant to the pump is used (In-line pumping), the friction loss in that supply line will become excessive as larger volumes are called for. Consequently, the incoming suction gauge on the pump will indicate only the Residual Pressure at the pump supplied by the limited volume of the single supply line, rather than indicating the total

potential available at the hydrant. In the sketch below, the 10 psi on the suction gauge of the pump is not a true indicator of the water available in the hydrant, but rather what is available through the hose layout used to the pump.



Under this condition, there may be a large volume of water available at the hydrant, but that large volume cannot reach the suction side of the pump due to the size of the supply line. To keep the friction loss in the supply line to a minimum, use a large supply line.

Using Direct pumping as shown, the 10 psi difference between Static and Residual, is an indicator of expected hydrant performance.



Two Engine Attack

The adaptability of this concept for a fire department will depend on a number of variable, such as the manning on each engine, the response time between first and second engines, type of water supply, etc. Each department should look at the possibility, if not already incorporated, of providing manning distribution for an effective Attack Pumper and Supply Pumper.

ATTACK PUMPER

This engine should take a key tactical position that will allow for the fastest attack with a punch, supported by a strong water supply for conditions encountered. Size-up may indicate In-line pumping is appropriate. However, under more serious conditions, the water supply for maximum flow should be at least two pumped lines from the second engine ON a hydrant.

There are advantages to positioning the Attack Pumper in close, but safe, proximity to the fire building.

1. Length of discharge lines is reduced.
2. Pump pressures are reduced.
3. Tools and equipment carried on the engine are readily available.
4. Operator has visual and verbal contact with fireground operations
5. Speeds attack with initial line placement, as well as additional line placement.

If this engine is tactically positioned, consideration should be given to putting it to capacity before committing discharge lines from other engines. Conditions, however, will sometimes require lines to other areas that can best be handled by a second attack engine position. In such cases, each attack engine should be supplied with an adequate, strong water supply.

SUPPLY PUMPER

Department SOP should be flexible enough to adapt to the various conditions encountered on the fireground, but should be directed toward having the second engine act as supply. Selection of a "key" hydrant, located closest to the building, should be made, unless predetermined main size and volumes requires otherwise. To take full advantage of the hydrant, connection should be made to the hydrant steamer connection via large soft suction.

CAUTION: Avoid crippling otherwise good hydrants with single unpumped hydrant lines.

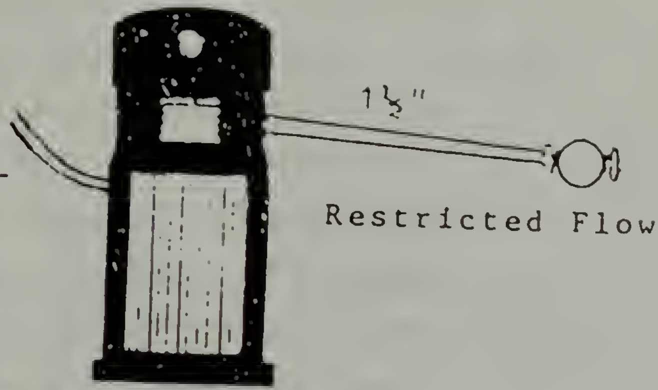
Pumpers connected to key hydrants can supply two or more pumpers in tactical forward positions. Officers on later incoming engines should consider laying in from a supply engine.

There are many options to implementing this two engine attack. One such option is the attack engine to lay out a 3" feed line to support its initial attack until the second engine can supply more water. This initial 3" feed line provides a partial supply to support initial attack in the event the second engine is late arriving due to mechanical failure, motor vehicle accident, or previous incident commitment.

Although the two engine concept provides an attack with provisions for adequate water supply, each engine company should be trained to be self-supporting.

EFFECTIVE CONNECTION TO HYDRANT

Previously we have discussed the need for a pumper to be set at a hydrant when supplying large calibre lines on the fireground. How the pumper is connected to the hydrant also may have considerable effect on moving the maximum amount of water the main is capable of delivering. If we place the pump at the end of a length of hose, the capacity the pump will deliver becomes restricted by the size of that hose. For example, if we were to use a short length of 1½" as a supply into a pump discharging a 2½" line, the residual reading on the pump would soon indicate a problem.



If we could some way connect the pumper directly to the steamer connection without the use of hose, perhaps the maximum efficiency in water movement could be achieved. Somewhere between these two extremes lies the type of pump tie-in to hydrants that will allow maximum flow for conditions.

Use of large soft suction, whether it be 5" or 6", directly off the hydrant outlet, will supply maximum volumes. However, two 3" short sections may be more suited to a particular evolution. For example, the attack pumper may itself lay dual lines off the 2½" outlets of a hydrant. The supply engine, coming in later, will then convert those hydrant lines to pumper lines, as shown in the addendum to this Chapter, using two 3" suction lines.

For large scale operations, operators should connect to the hydrant via large soft suction when possible.

The Blitz Attack

Briefly described, the Blitz provides a discharge of a large volume of water, through a 2½" handline or master stream, from the tank water of the attack pumper, for a quick knockdown of the fire. This concept of attack recognizes it takes volumes of water to put out volumes of fire, and a fast application is the best approach to pre-

vent extension. This is a gamble, all eggs in one basket attack that should be attempted only when:

1. Conditions permit easy access to main body of fire, such as fire overlapping out store front.
2. Water supply support will be quickly attached to the attack pumper for back up and continuous application.

This type of attack puts particular importance on the supply engine. Radio communications, therefore, are vital. The attack engine must know that the second engine's arrival will not be delayed, and must notify the second engine that the Blitz attack has been selected. It must be understood that the Blitz attack may lead to the attack pumper running out of water. Don't worry about it. Knock down will be accomplished and the supply will be available to provide mop up.

Before attempting a Blitz attack, some points must be examined:

1. Capacity of equipment. Piping from the tank to the suction side of the pump may limit volume of discharge. Tank capacity will also weigh heavily on the success of a Blitz.
2. Concentrated training is essential to the success of this evolution. Men must know the limitations and what to expect.

Supplementary Pumping

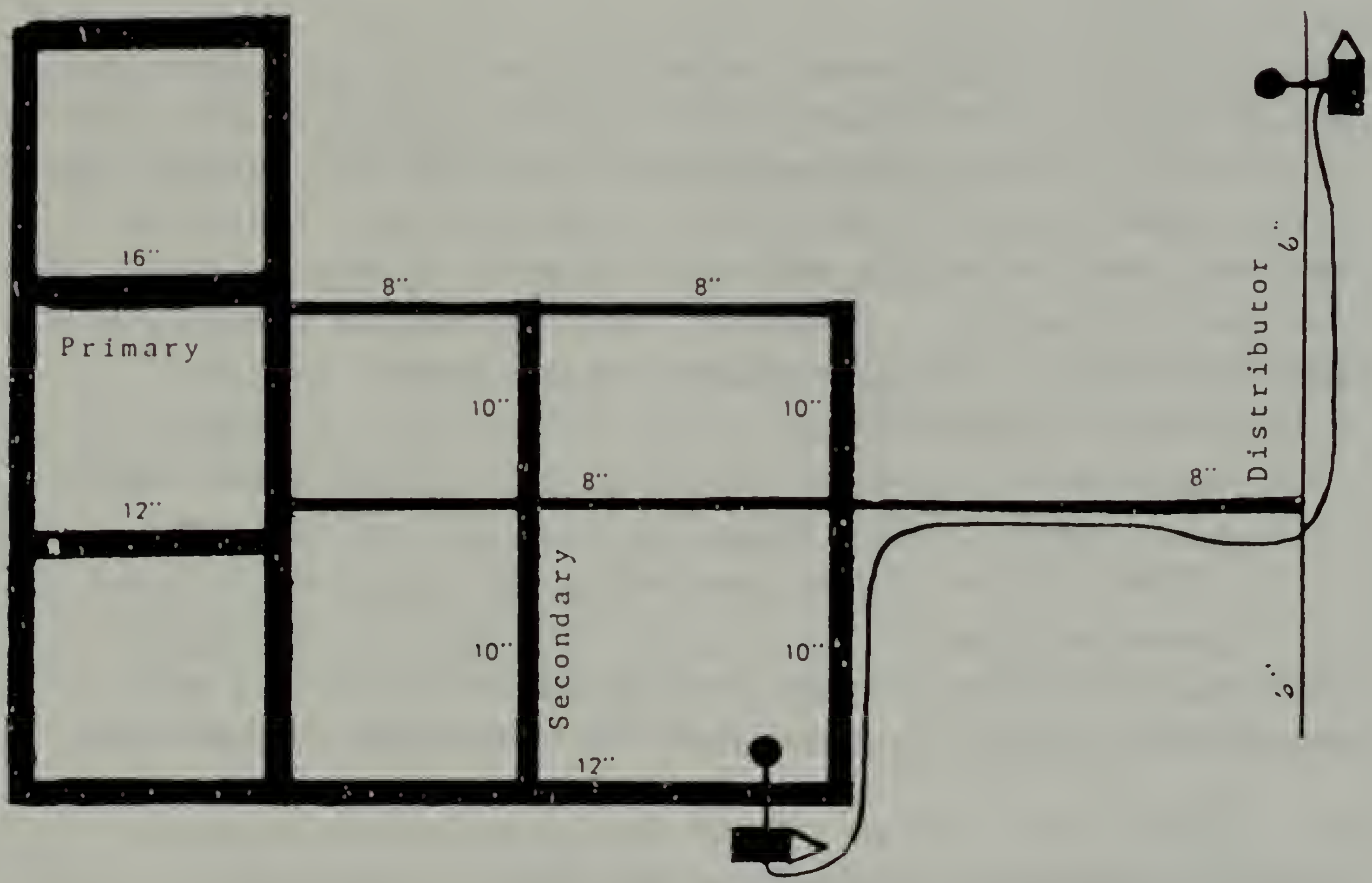
One of the common problems that arises at serious fires is the depletion of water supplies from mains in the immediate vicinity of the fire. This condition is apt to occur at fires where the demand for water is excessive, such as where several heavy stream appliances are operating in combination with numerous hand lines to control such fires. The situation will naturally be more acute in those areas where the mains are too old and too small to supply the demand created by the fire problem. Such conditions will be apparent to pump operators by low residual readings on the pumps.

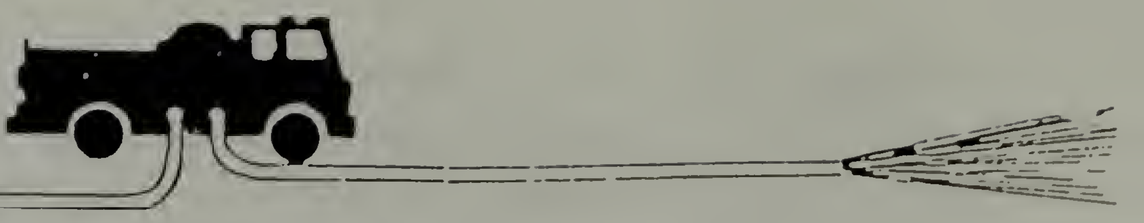
Where water main systems are so arranged as to be interconnected into grid or looped systems, water may be available in abundance one or two streets away, on larger mains. Supplementary pumping is intended to move water from the abundant source to the depleted fire area. (Supplementary pumping differs from relay pumping in that Supplementary adds to a supply already established.)

PROCEDURE

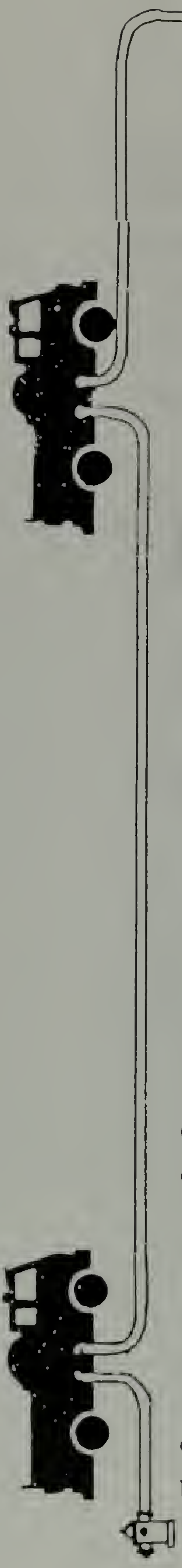
The principle involved is simply to move additional water into the suction side of a pump at or near the fire in order to increase the residual pressure and improve operations. A 2½" or 3" line is laid and attached to the 2½" auxiliary intake on the forward pumper. The supply pumper takes its position on the selected hydrant by connecting to the steamer connection with large soft suction.

Operators of supply engines should set pump pressures in accordance with the length of line and anticipated flow. In most cases, the pump should be in the pressure stage and pump pressures in the area of 100 psi to 150 psi are common.





Relay Pumping



Relaying water by placing a number of pumpers in series to move water an extended distance is probably one of the least understood evolutions, simply due to it infrequent use. Fire departments in rural areas are most adept at this evolution, since absence of municipal water systems requires use of distant static sources. Even in urban departments, however, the relay operation becomes necessary. A community with limited access highways, for example, may have to move water considerable distances.

Much has been written about relay pumping, including formulas and fraction for determining the distance one pumper should be from another, as well as suggestions for where the largest capacity pumper should be set, etc. Most experience indicates, however, that the best policy is to <u>keep</u> <u>it</u> <u>simple</u>, yet hydraulically practical. Basically, when setting up for a relay operation, the following should be considered:

1. Select a pumper to set at the source.
2. Each pumper in the relay should lay out its hose, then set.
3. Each pumper (except fireground pumper) should discharge at 200 psi EP, and, with multi-stage pumps, be in the pressure stage.

These basic points are based on the understanding that most pumpers are carrying approximately 1000' of hose in their bed.

Once set up, the operator of the fire scene pumper should compute incoming pressure and volume just the same as at a hydrant. Pressures on the suction side of the pump should not be allowed to fall below 10 psi, preferably not less than 20 psi.

Pumpers should discharge water at pressures that are below that for which the hose is normally tested. Hose testing to ISO standards will be at 250 psi. To stay within safety limits, discharge pressures in excess of 200 psi should be avoided when possible

It must be remembered that when pumpers are placed in relay, and operating at approximately 200 psi, approximately 250 to 280 GPM is available when using one 2½" supply line. Discharge pressures are directly related to pumper output, as set forth in the Acceptance Test, stating the pump shall deliver at draft:

100% of its rated capacity at 150 psi EP
70% of its rated capacity at 200 psi EP
50% of its rated capacity at 250 psi EP

These capacities may be exceeded under favorable hydrant conditions

NOTE: The above chart provides reason for the lack of support of 2" tips (1000 GPM) on master streams. Few layouts leading to 2" tips require less than 150 psi EP. A 1000 GPM pumper, pumping in the area of 200 psi may be capable of only 700 GPM and therefore cannot support a 2" tip.

Consideration should also be given during relay operations to the use of dual supply lines when possible. When friction loss becomes so great it restricts or prohibits moving water effectively, the answer may be the use of siamesed lines to reduce such loss.

There are a number of cautions that must be considered when electing to use relay operations:

1. Make sure operations are performed slowly to eliminate water hammer or other complications that may result from haste.
2. Know the limitations of the layout from the aspect of both time and flow.
3. Don't expect to put a deck gun at the end of a 4000' relay. Know what you can do.
4. Don't pump at 300 psi EP when hose is tested for only 250.
5. Remember, the harder the pump works, the less water it can discharge.

A rule of thumb for determining relay capability (using single 3" line)

200 psi EP
-20 psi Residual at 2nd pumper
180 psi Friction loss

Divide the total layout between pumps by 100 $\frac{1000' \text{ layout}}{100} = 10$

Divide the FL figure by the # of 100' lengths (in this case 10)

$\frac{180}{10}$ = 18 lbs FL/100'

Friction loss in 3" hose is determined by squaring the first figure of the flow. With 500 GPM, 5 X 5 = 25 lbs FL per 100'.

The 18 psi in the previous problem is then converted to a flow by finding the closest square root of 18, which is 4+. Therefore, this relay operation can move a little more than 400 GPM, using 3" hose.

18 psi FL represents a flow of 280 GPM in 2½" hose.

Length of 3" lay	1000'	900'	800'	700'	600'	500'
Flow capacity	420	450	470	500	550	600

Remember, the longer the supply line, the smaller the flow at the pump. Any pump can only work with whatever water is brought to it.

Supplying Fixed Systems

SPRINKLER SYSTEMS

Every officer must recognize the need for sprinkler systems to be supported with pumper lines early into a fire in sprinklered property. Pumpers connected to nearby water mains can deplete water from a normally operating sprinkler system, rendering the system ineffective. However, with pumper lines feeding into the sprinkler siamese, effective pressure can be maintained on the sprinkler system, even though residual pressure on the street water main has been reduced. Each department should consider the need for an SOP to insure water supply to the sprinklers is not overlooked. Consideration may be given to employing the second line from the attack pumper, or a line from the second pumper to feed the system.

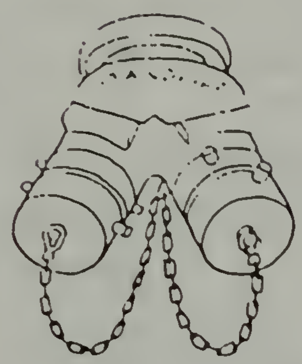
When supplying sprinkler systems it should be remembered that:

1. Normal discharge from one head is approximately 25 GPM
2. A 2½" line, carrying capacity of 300 GPM, will supply about 12 heads.

Engine pressure required for a sprinkler line must be sufficient to provide 150 psi at the siamese. If the operator notes a drop in residual pressure after initial operations, it may be a sign that additional heads are operating, and an additional line should be connected into the siamese.

STANDPIPES

As with any fireground operations, pencil and paper or formulas have little place with standpipe supply operations. Rule of thumb calculations will be satisfactory. Most fire departments do not rely on the standpipe hose provided for occupants, but instead use fire department hose and nozzles. Again, nozzle pressures of 100 psi will be necessary for effective use of such nozzles. Using 5 psi elevation for each story water is to be raised, engine pressures can then be determined by adding:

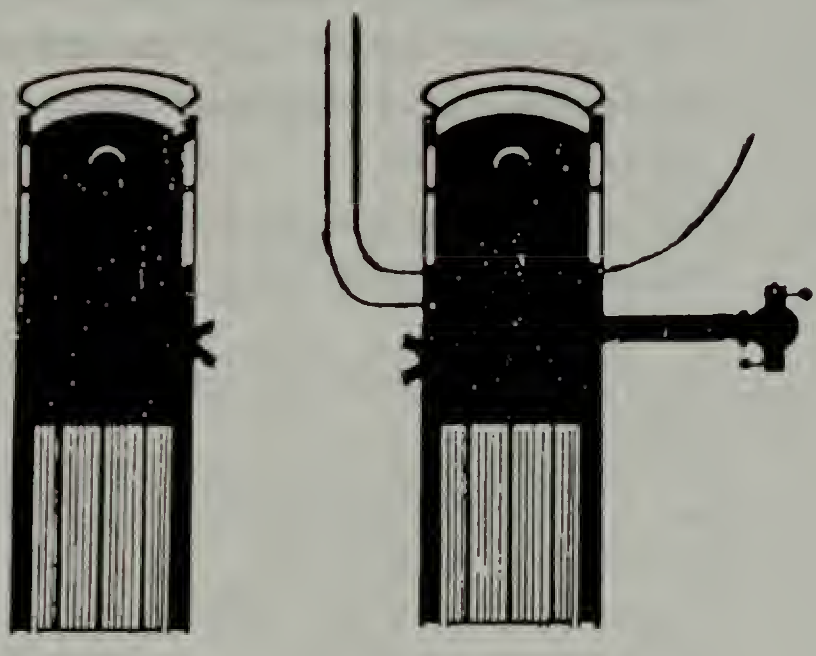


100 psi NP
25 psi Elevation (for 5th floor)
25 psi FL in system
150 psi EP (at the siamese)

In the case of high rise, electric pumps are generally provided to supply standpipe systems. However, during power failure, pumpers may have to provide supply. Under conditions where a pump is expected to supply a standpipe system with an incident on the 30th floor or above, pump pressures may be excessive or even prohibitive. Thought should also be given to the pressure hose lines used for supply are expected to withstand.

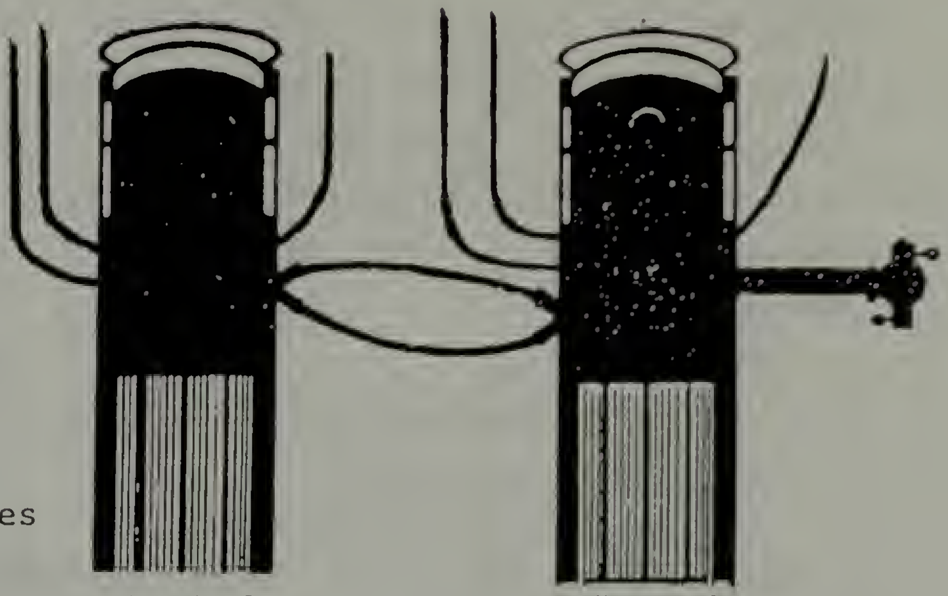
Tandem Pumping

Tandem pumping allows for the maximum use of a water main through one hydrant. If a hydrant, attached to an excellent main (such as 16", 24", or larger), is capable of delivering something in the area of 3000 GPM or more, the first pump connected will reach capacity of the pump with a substantially high pressure remaining at the pump. In some cases, this hydrant may be strategically positioned, and since the residual pressure on the first engine indicates considerable volume remaining in the main, a tandem pumping operation would have a second



PUMP 2 PUMP 1

pumper take its supply from the suction of the first pumper. This process allows not only the maximum use of a "key" hydrant, but eliminates the need for the second pumper to take another hydrant where long lays may be necessary



PROCEDURE:

1. Pumper 1 sets according to recommended precedure with large soft suction, leaving siamese free.
2. Pumper 2 takes position with proper distance between the siameses of each pump. 3" short sleeves are attached (double males necessary).
3. 3" sleeves are attached to the siamese on the suction side of pumper 1, gates on both siameses are opened, and the water is passed through pumper 1 into pumper 2.
4. Pumper 2 charges discharge lines to fire. Both pumpers are fed from the same hydrant.

Summary

When considering the provisions for water supply on the fireground, thought should be given to:

1. Establishing and training for suitable SOP that will insure a strong supply to support extinguishment efforts. The terms "Socialized" or "Free Enterprise" firefighting refers to the loose type of fireground operations where each company does what it feels effective, without overall control or coordination. SOP's, although flexible, designate particular responsibility as well as accountability for each company, especially first alarm response.
2. Analysis of large scale operations after the incident to determine effectiveness.
    a. Should adjustments be made with SOP's?
    b. Accountability. If there was deviance from SOP, why was such action taken?
3. Fireground analysis is a learning experience that can lead to better operations, based on sound decisions that come from good knowledge.

LARGE DIAMETER HOSE

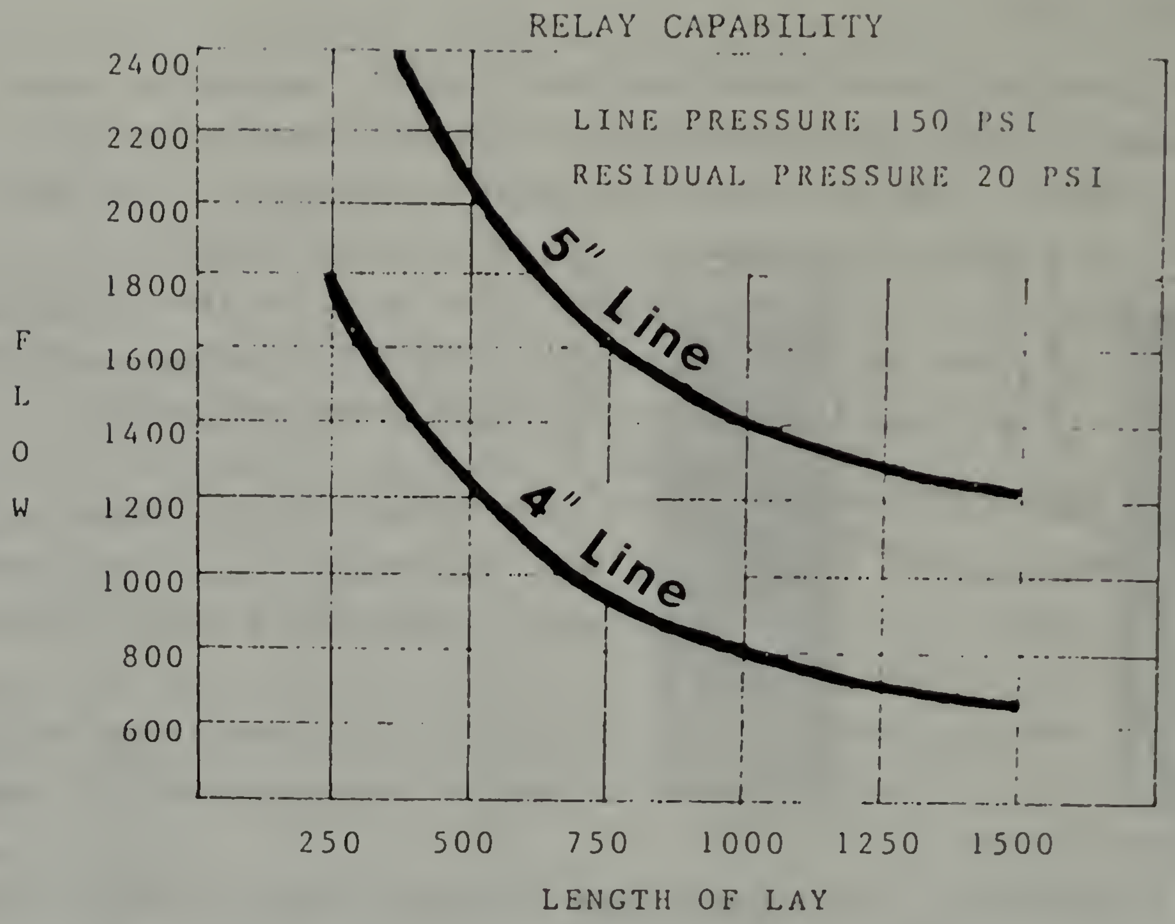
In search of procedures to make the best use of resources, many fire departments have discovered that large diameter hose provides a valuable means to the refinement of such procedures. The National Fire Protection Association defines large diameter hose as: "A large diameter, lightweight, single jacketed fire hose designed to move large volumes of water at low pressures". For the purpose of this text, the definition shall involve diameters from 4" to 6".

As previously explained, the Officer-in-charge must be familiar with the carrying capacity of hose lines and the municipal water system, or other water supplies, The water supply available on the fireground is limited by the following factors:

1. VOLUME. Static sources and some municipal or private water systems are limited in total volume by the capacity of tanks, rservoirs, etc.
2. FLOW CAPABILITY. Municipal water systems vary in flow capability, dependent on the length of piping, diameter of piping, and the pressure available at the source to overcome friction loss and back pressure.
3. PUMP LIMITATION. When evaluating pump limitation, the type of source (static or pressure) must be considered and the <u>net</u> pump pressure required as pump capability is greatest at low net pump pressures.
4. HOSE LIMITATION. Friction loss in hose lines frequently presents the greatest limitation in fireground water supply. Friction loss is dependent on the flow, diameter of supply lines, and length of lay. Therefore, even with dual lines and pump set at an adequate hydrant, the layout may not adequately supply a 1250 GPM pumper without large diameter hose.

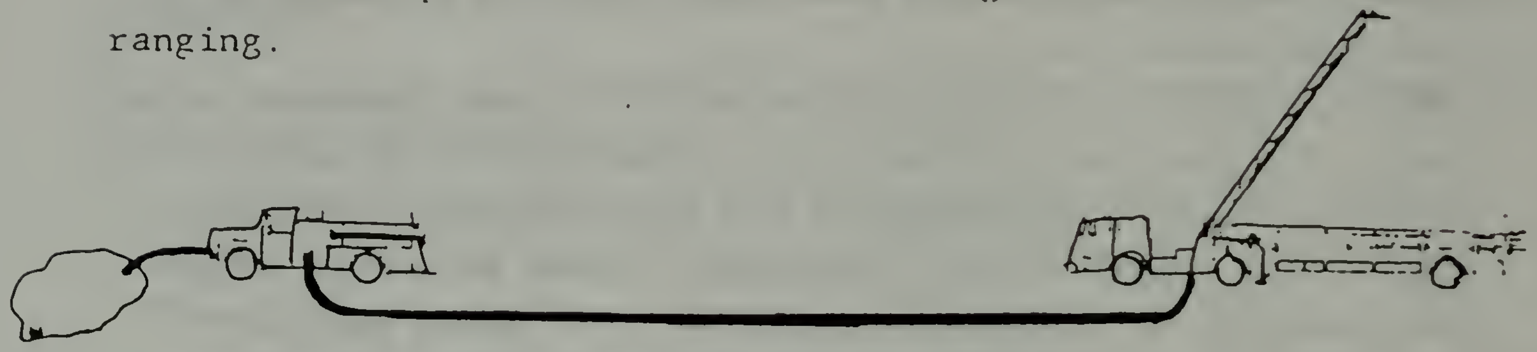
Consideration should be given to use of adequate hose size that will take full advantage of the available water supple and the pumping capacity of engines; not just rated capacity, but <u>full</u> capacity.

Some of today's building design and construction lends itself to rapid burn and/or early collapse, causing some adjustments in the strategy of initial attack techniques. A quick attack with large volumes of water in the first few minutes therefore is sometimes



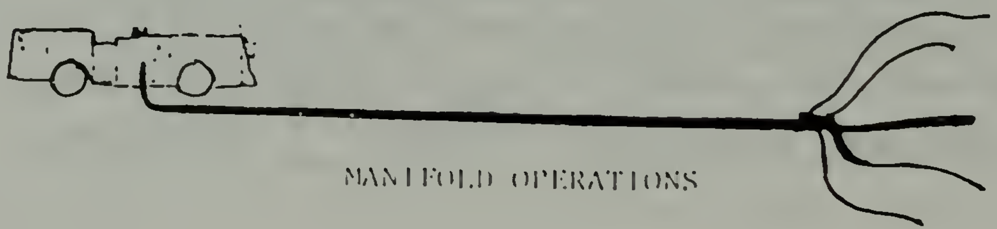
required by these types of incidents. The use of large diameter supply lines allows increased flexibility with inline pumping (greatest flow or length of lay) and reduces the time, personnel, and apparatus required to develop a given flow.

The tactical options for the use of large diameter hose are wide ranging.



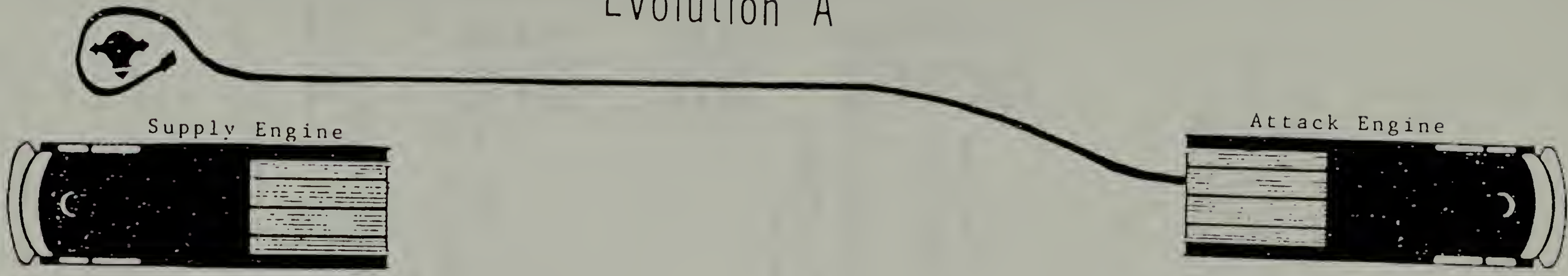
MASTER STREAM OPERATIONS

RELAY OPERATIONS



MANIFOLD OPERATIONS

Evolution A

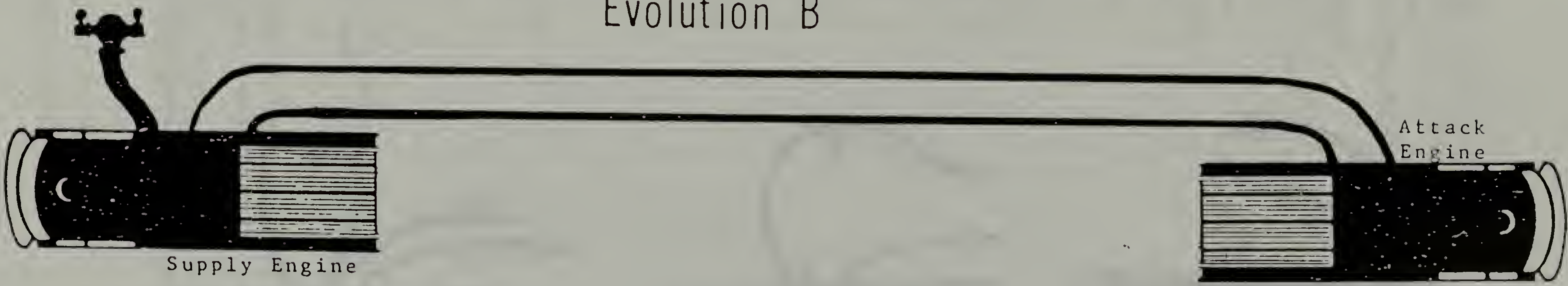


This evolution has the Attack Engine laying its own supply line and leaving it uncharged. The purpose of this is to eliminate total dependence on a second engine for supply. Incidents such as motor vehicle accidents or mechanical problems may prevent the second engine's arrival. Two options exist with this evolution:

A. If the second engine doesn't arrive, one man is sent to dress and open hydrant

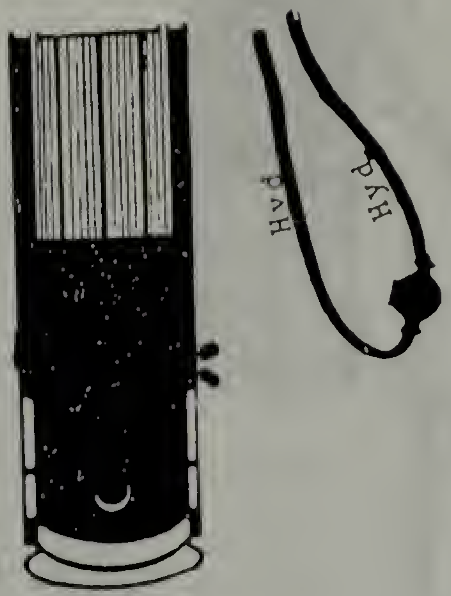
B. When second engine arrives on schedule, it assumes its normal supply duties.

Evolution B



This evolution provides for the Attack Engine to go directly to the fire. The second engine assumes a supply assignment, and lays two lines from the Attack Engine to the source. Consideration must be given to the packing of hose beds for this evolution. Often, one side of a divided bed will be packed <u>source to fire</u>, the other <u>fire to source</u>.

Position 1

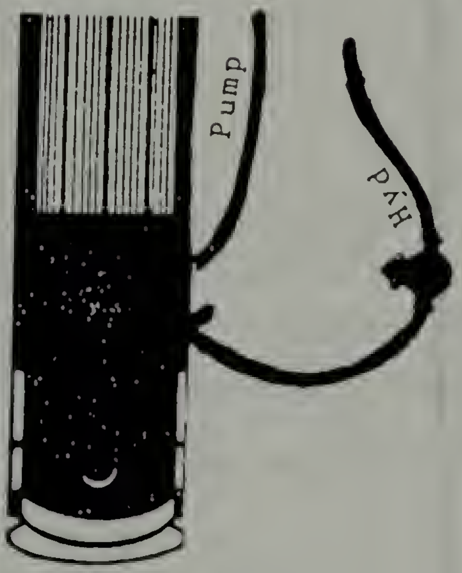


When converting hydrant lines to pumper lines, one line is shut down at a time as shown.

POSITION 1

Two hydrant lines have been laid to fire. Pump takes a position and readies two 3" lengths of soft suction.

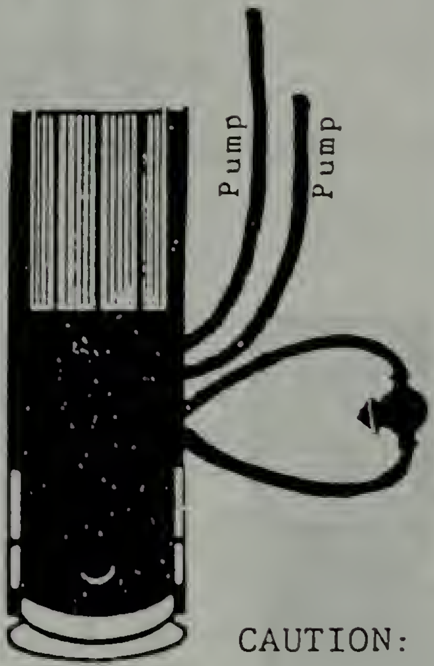
Position 2



POSITION 2

A. Hydrant line is shut down and transferred to discharge gate on pumper.
B. 3" suction line is attached from pumper to hydrant and charged.
C. Discharge line is charged.

Position 3



POSITION 3

A. Second hydrant line is shut down and transfered to discharge gate on pumper.
B. Second 3" suction line is attached to hydrant and charged.
C. Discharge line is charged.

THIS EVOLUTION REQUIRES THE DOUBLE GATING OF 2½" OUTLETS.

CAUTION: If hydrant lines are fed into a non-clappered siamese, there will be back feed of pressure when line is shut down. In such cases, the line should be clamped before disconnecting

MASSACHUSETTS FIREFIGHTING ACADEMY
DIVISION OF OCCUPATIONAL EDUCATION

SIMPLIFIED HYDRAULICS FOR FIREGROUND USE

HAND LINE DATA

NOZZLE PRESSURE FOR ALL HAND HELD LINES

Solid stream 50 LBS. — Combination 100 LBS.

FLOW — GPM.	FRICTION LOSS PER 100 FT.	
	Booster Hose	
	¾"	1"
12 GPM.	25 LBS.	5 LBS.
15 GPM.	30 LBS.	7 LBS.
18 GPM.	40 LBS.	10 LBS.
20 GPM.	50 LBS.	13 LBS.
23 GPM.	60 LBS.	15 LBS.
25 GPM.	75 LBS.	19 LBS.
30 GPM.	105 LBS.	26 LBS.
35 GPM.	140 LBS.	35 LBS.
	1½" Hose	
50 GPM.	10 LBS.	
80 GPM.	20 LBS.	
100 GPM.	30 LBS.	
125 GPM.	50 LBS.	
	2½" Hose	
100 GPM.	— LBS.	¾" TIP
150 GPM.	5 LBS.	⅞" TIP
200 GPM.	10 LBS.	1" TIP
250 GPM.	15 LBS.	1⅛" TIP
300 GPM.	20 LBS.	1¼" TIP

The accepted nozzle pressure on all 2½" hand lines, using solid streams is 50 LBS. With that pressure, a definite value can be associated with every tip used on a 2½" hand line, as shown in the above chart.

The flow from any combination nozzle will vary with the make and style of the nozzle. Manufacturers literature should be consulted for verification of the flow from a particular nozzle.

To find the friction loss in 2½" hose with up to 400 GPM. flowing, drop the last digit of the flow in GPM. and reduce the first digit by one (1). This figure is the friction loss per hundred feet of 2½" hose with that amount of water flowing.

EXAMPLE: With a 1⅛" tip, the flow is 250 GPM. With 250, strike out the last digit, 25~~0~~: now you have 25. Then reduce the first number by one, as ~~2~~5 = 15, and you arrive at 15, which is the loss per 100 feet of hose. Do this with all flows up to 399 GPM.

To find the friction loss in 2½" hose with 400 or more gallons flowing, cross out the **last digit** only.

EXAMPLE: 1. 40~~0~~ = 40 LBS. per 100 feet.
EXAMPLE: 2. 50~~0~~ = 50 LBS. per 100 feet.

DETERMINATION OF ENGINE PRESSURE

To find the engine pressure once the nozzle pressure and friction loss have been determined, add the friction loss and the nozzle pressure as in the following formula.

E.P. = N.P. + F.L.

EXAMPLE: 300 feet of 2½" hose with a 1⅛" solid stream nozzle

EXAMPLE: Flow = 250 GPM. Friction loss = 15 LBS. per 100 Feet

E.P. = 50 + 3x15 = 95 LBS.

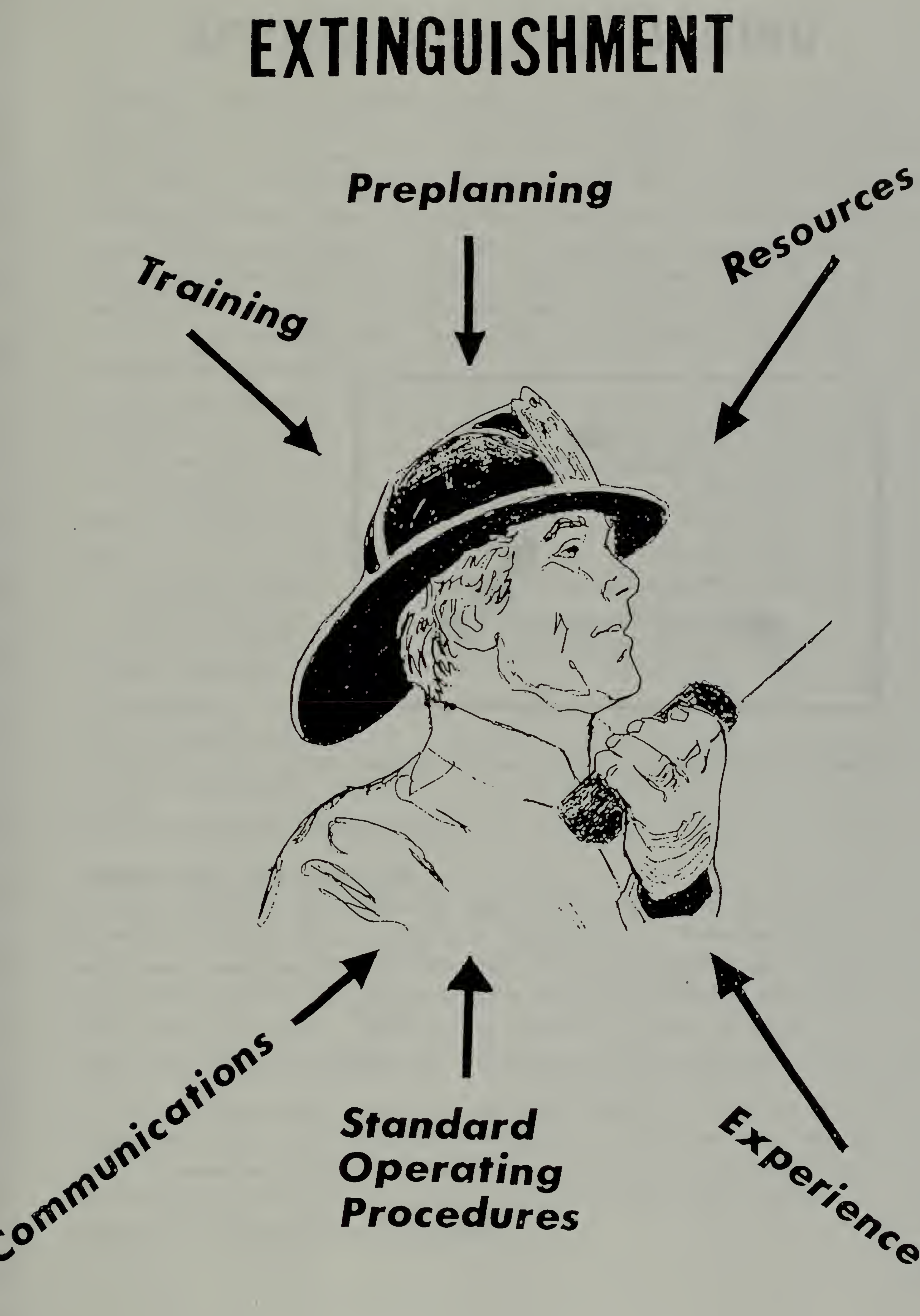
FIREGROUND HYDRAULICS

CARRYING CAPACITY OF HOSE

NORMAL HOSE DIAMETER IN INCHES.	MAXIMUM EFFICIENT WATER CAPACITY IN G.P.M.
3/4"	12 GPM
1"	35 GPM
1½"	100 GPM
1 3/4"	150 GPM
2"	200 GPM
2½"	300 GPM
3"	500 GPM
3½"	750 GPM
4"	1000 GPM
5"	1500 GPM

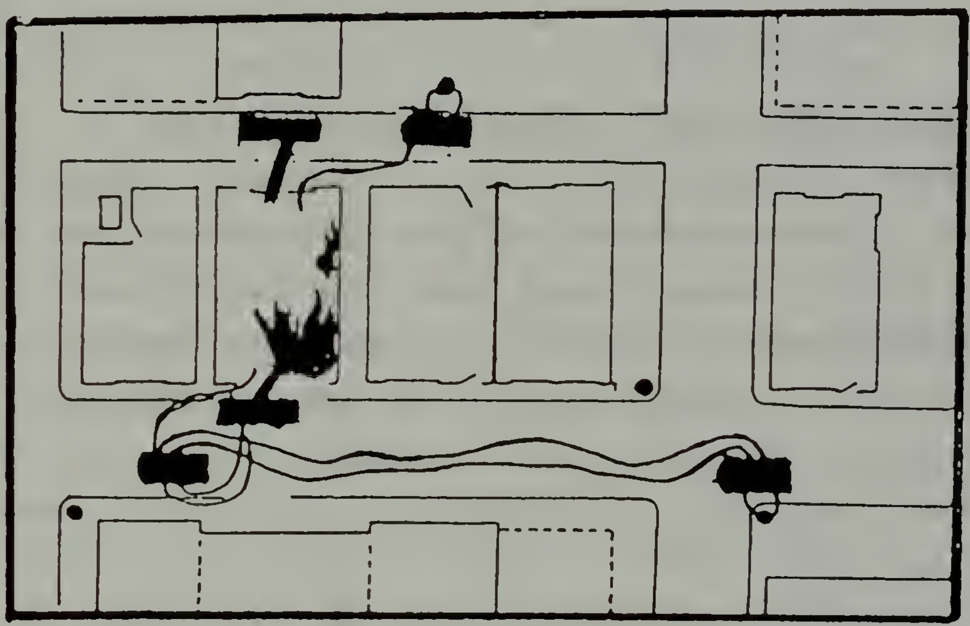
Larger flows are possible through the various size hose lines but with appropriately larger friction loss. Flows shown are flows available at approximately 20 PSI. friction loss/per 100 ft.

EXTINGUISHMENT



APPARATUS POSITIONING

Effective apparatus placement begins with the arrival of the first due units, based on initial size-up of conditions. With effective placement of first due units, later arriving units can be positioned in a manner that builds on the initial plan, and allows for expansion of the operation. Since firefighters often have a tendency to drive their vehicles as close to the fire as possible, decisions must be made and transmitted that reflect a plan to not only take full advantage of equipment, but that minimizes collection and congestion close to the fire building, caused by idle or inactive apparatus.



In order to effectively utilize apparatus, placement on the fireground should be a reflection of one of the following:

1. A Standard Operating Procedure.
2. A direct order from the Officer in Charge.
3. A conscious decision on the part of the company officer, based on existing or predictable conditions.
4. A pre-arranged staging area.

STANDARD OPERATING PROCEDURE

In depth pre-fire planning will indicate hydrants that may best serve the initial attack efforts. Coupled with a knowledge of main sizes and flow figures, Standard Operating Procedures should be established within each department to guide officers regarding positioning decisions. However, no procedure should be used as a substitute for the judgment and initiative of the company officer.

It must be remembered that communications serves a vital part in effectiveness of the fireground operation. First due units must radio fireground conditions, including position, particularly if such position varies from an SOP. Late arriving units must be prepared to adjust to the situation.

First arriving company is normally assigned to the front of the building, unless otherwise directed by the officer-in-charge. With nothing showing from the outside, or when tank water is to be used for attack, the attack engine should generally stop just beyong the fire building, thereby facilitating:

1. Proper size-up by allowing the officer to view three sides of the building.
2. Positioning aerial ladder in front of the building. Priority should be given to aerial ladder placement for upper level rescue and venting, using ground ladders for lower level windows.
3. Easy advancement of pre-connected attack lines, where such lines discharge from the rear of apparatus.

A DIRECT ORDER FROM THE OFFICER-IN-CHARGE

Foremost in the mind of the officer-in-charge, as previously mentioned, is to position early arriving units in such a manner that later arriving units can build on the initial positions, thereby strengthening the attack. It must be remembered that often, once apparatus is committed to a particular position, as fire conditions worsen and additional apparatus arrives, original positions become fixed for the duration of the fire. Therefore, consideration must be given to:

1. Avoiding positioning that may contribute to congestion in the immediate vicinity of the fire building. SOP's are designed to ease congestion, as well as facilitate fireground operations.
2. Apparatus as an exposure.
3. Coverage of the rear of the building, which may not be easily accessible.
4. Avoid blocking narrow alleys or restricted passageways.
5. Taking advantage of pumps that are in good tactical positions before committing lines from other pumps.
6. Visibility of command vehicle. Initial position should be communicated, as well as any position changes.

CONSCIOUS DECISION ON THE PART OF THE COMPANY OFFICER, BASED ON EXISTING OR PREDICTABLE CONDITIONS

Standard Operating Procedures have considered key positions that offer maximum fire attack access to the fire area, with quick, adequate water supply. However, size-up by the first due officer may dictate placement that varies from the SOP. When it is nec-

essary for the officer to vary from the SOP, for tactical reason he must still make allowances for future operations.

Most often it is not command decisions that determine position, but rather the decision of the company officer on the unit. Such officer must remember:

1. Do not park vehicles in a manner that may restrict other apparatus, such as;
   a. incoming apparatus. Every effort should be made to maintain an access lane down the center of the street.
   b. committed apparatus. Do not park behind already stationary apparatus, especially ladders (i.e. preventing removal of ground ladders)
2. Company officers must give consideration, when locating uncommitted apparatus, to eliminate congestion, yet remain in readiness. As an example, when an attack engine reports nothing showing, the second engine may take a position up the street, but ready to stretch a feed line upon request. Such position should allow the flexibility to proceed to the fire area, or away from it in the event of another call.

PRE-ARRANGED STAGING AREA

The previous statement is an example of a Staging Area. This concept may be particularly important at the large scale fire. The officer-in-charge should consider an alternative to bringing uneeded apparatus directly to the fire scene. Such an alternative is the staging area (parking lot, vacant lot, etc.) from which the OIC can draw units as needed.

SUMMARY

Good apparatus positioning will complement the overall fireground operations. SOP's are aids that can lead to effective placement. However, in the absence of SOP's, officers must be aware of the pitfalls of improper placement as it affects operations.

Each large scale operation can be a learning experience for the purpose of improving operations, if properly analyzed after the incident. Operations, particularly apparatus placement, should be discussed for it effectiveness and possible adjustments in the future.

STRATEGY - A PLAN OF ACTION

Tactics and Strategy, when used to describe fireground operations, are perhaps seldom considered as two separate steps. Webster looked at Strategy as the science or art of command, exercised to meet the enemy in combat under advantageous conditions - a careful plan or method of attack. Tactics, on the otherhand, is the art or skill of employing available resources to accomplish the plan. Therefore, if Strategy is the "What" is to be done, Tactics is the "How" it is to be done. The Officer-In-Charge, after a thorough size-up, will determine a strategy, based on conditions present, which may set as a priority, getting ahead of the fire on the third floor. Soon after establishing his strategy, he will implement his tactical approach, the first step of which may be to get a 2½" line ready for advancement over the fire escape as ventilation is being accomplished topside.

AN OVERALL LOOK AT THE FIRE CONDITIONS

The luxury of time is denied the Officer-In-Charge in the decision making, for the problem at hand is not static, but continues to grow in intensity and complexities. A demand is made on the OIC's concentration, expertise, and rapid implementation of the firefighting forces available.

Many factors contribute to the commitment of the firefighting forces. No matter how severe a fire situation is, if the building is occupied, the entire resources at hand have to be employed in entering, or in an attempt to enter the building for search and rescue purposes. When a building cannot be entered immediately, there may be a need for a combination of hand lines and heavy stream appliances, working in close coordination with each other. At the very first sign that hand lines have entry capability, lines should be advanced into the building, while outside lines are placed in a standby position. Strategy is based on a size-up of the total picture.

INSIDE FIREFIGHTING

Building Fire With Human Life Involved

An aggressive hose line attack is made to safeguard occupants and to establish safe escape routes for both the occupants and firefighters. Ventilation procedures are carried out to direct and channel heat, smoke, and gases away from the occupants, and allow search and rescue teams, along with the extinguishing operation, to aid the orderly exit of occupants of the building to the outside

and to an area of safety.

Building Fire With No Life Hazard

An aggressive hose line attack is made to the seat of the fire. First hose line is followed by second line to help in the extinguishment of the fire, prevent extension, or for the protection of the firefighters involved in the extinguishment operation. Ventilation procedures are carried out to relieve pent up heat, smoke and gases, and to allow entry into the building by firefighters. Overhead ventilation is dictated by the location of the fire below.

Lateral and cross ventilation can follow as fire conditions show the need for further relief from heat and smoke.

MULTI-STORY BUILDINGS - CONSIDERATIONS:

Life Hazard
Sufficient Help
Location of Fire
Extent of Fire
Intensity of Fire
Number of Floors Involved
Area of Floors
Construction
Internal and External Exposures
Occupancy

If more than one floor is involved in a building fire, hose lines should not be advanced above the fire floor and placed into operation until a hose line has been placed into position and into operation on the lowest floor involved in fire. The number of hose lines necessary on a given floor involved in fire will depend on the size of the floor area, extent of fire, occupancy, and capabilities of the firefighting forces to maintain a position for extinguishment. Then, and then only, can hose lines advance over stairways, fire escapes or outside ground ladders or aerial ladders to the floors involved in fire above the lowest fire floor. This procedure is then enacted again and again as progress is made from floor to floor, depending on the number of floors involved.

There will be occasions when, upon arrival at a large building fire, heavy streams will be the only practical method of control, containment, and extinguishment.

The height of the building will dictate whether ladder pipes, articulating booms, deluge sets, portable deck guns, or stationary guns mounted on apparatus will serve the purpose of control and extinguishment.

OFFENSIVE STRATEGY

Upon arriving at a building where smoke and/or fire are showing, there must be a basic and pacesetting decision made by the Officer-in-charge to institute an Offensive or Defensive attack on the fire.

If the OIC, deems that the building is tenable, and the fire can be confined, an aggressive coordinated Offensive Attack on the fire should be ordered. The OIC's most immediate action upon arrival should be to take command, size-up, and issue clear, direct orders, thereby coordinating the assault on the fire and eliminating free lancing by arriving company officers.

There must be, particularly at the earliest stage of the fire, a concerted effort to determine where the fire is going in terms of vertical and horizontal travel. Factors that must receive consideration in sizing up an offensive attack are avenues that may provide means of rapid extension, such as openings in construction, large open area, doors to apartments and rooms left open, wind direction and velocity, and vertical shafts.

In order to coordinate operations, the OIC must assign specific working locations to the incoming companies, with goals to be acheived. In so doing, each company commander will be responsible for his assigned area of responsibility.

An Offensive Attack means confronting the fire with an offensive attitude. It means overpowering the fire and stopping it where it's found; engaging it from the unburned-interior side, and pushing it out of the building. In order to accomplish such a strategy, line placement and stream management must take advantage of the ventilation already done by the fire, as in the case of fire overlapping out of an opening in the building. Initial efforts should be concentrated towards saving endangered life in the building and conservation of property by channeling the fire out and away from internal exposures.

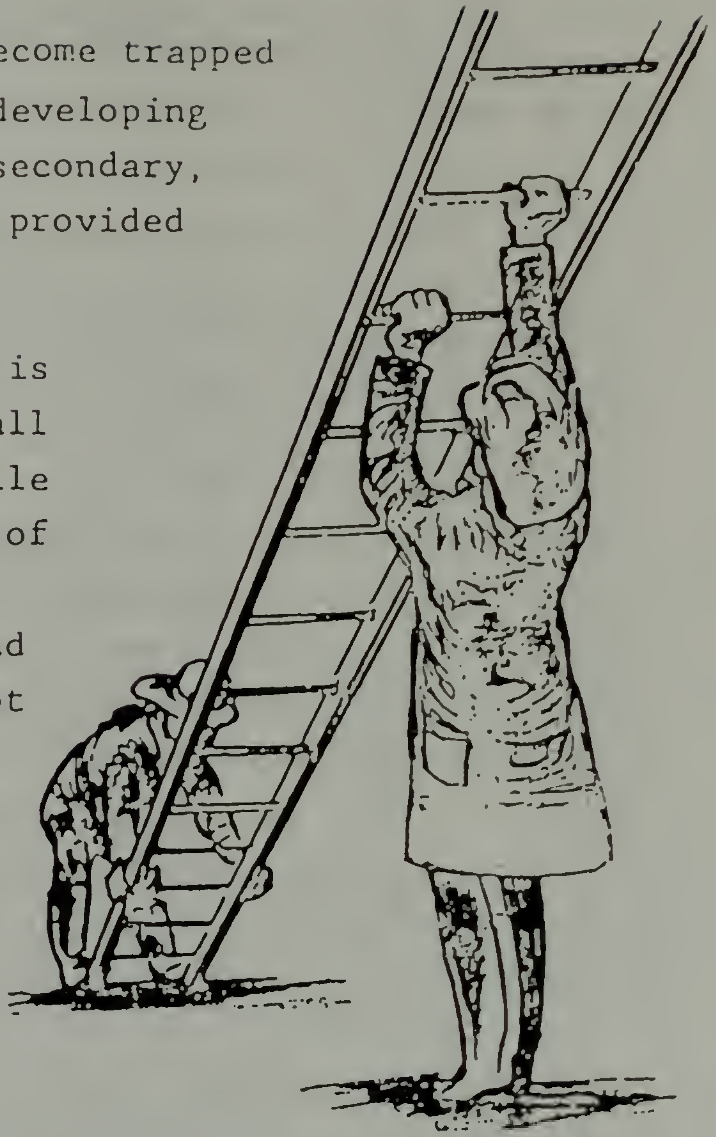
A critical factor when deciding in favor of the offensive mode is that consideration be given to the initial water supplies at hand to support the initial attack efforts. Water tanks on the apparatus will provide for fast application from handlines and apparatus mounted heavy stream devices. The OIC will have to evaluate the problem faced, against the option for a quick tank supported attack, or a slower, long range approach of connecting immediately to water mains.

In any offensive tactical operation, when life hazard is the prime consideration, a fast, well placed attack, using handlines to cut off the fire from the endangered occupants, may well solve the immediate rescue requirement. Such an approach is more apt to allow occupants to traverse hallways and stairways to a place of safety, than require the more hazardous route over ground ladders or aerial. It is the use of handlines during rescue operations that allows two key functions to be carried out simultaneously; the provision of protection for both occupants and firefighters, and the confining and extinguishing of fire.

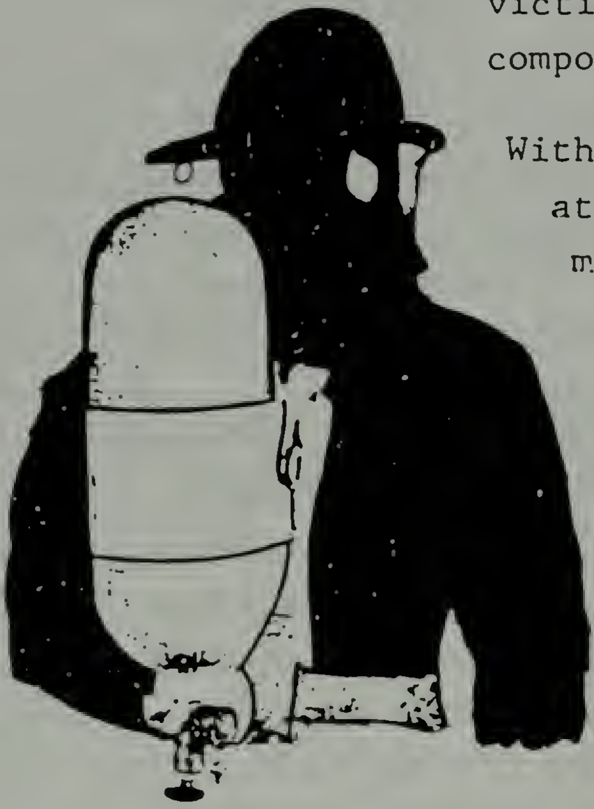
An Offensive Attack is NOT merely directing streams haphazardly into dense smoke. With a true offensive attitude, officers will see that companies operating lines are actually putting water on on the fire. Prior planning will provide nozzles that allow various flows and spray/straight stream patterns to be selected that will permit the operating forces to combat the fire from a safe vantage point. It will be the OIC's responsibility to prioritize and assign specific operating positions for attack lines, as well as provide secondary lines to afford back-up coverage for attack lines, and cover adjacent and overhead exposures.

In order to commence and carry out a successful interior Offensive Attack, specific and timely support activities must be assigned incoming companies. Ladder work, both aerial and ground ladders, may be necessary for immediate rescue from windows or rooftops. Timely and properly placed ladders serve the function of rescuing occupants, ventilation to relieve the building of pent up heat, smoke and gases, allowing occupants to evacuate the building and firefighters to enter; search and rescue those trapped occupants; and future firefighting activities. The OIC must keep in mind

that firefighters themselves may become trapped in the building, due to a rapidly developing interior fire, and will require a secondary, quick means of escape that will be provided be strategically placed ladders.



Self-contained breathing apparatus is absolutely essential equipment to all firefighters operating in the hostile environment. The primary function of rescuing endangered occupants, protecting and preserving property, and reaching the seat of the fire cannot be accomplished in a smoke filled building without benefit of air masks. Therefore, when ordering an Offensive Attack, the OIC must insist that masks be utilized. Men without masks oftentimes cannot penetrate a hazardous atmosphere; cannot effect rescue; cannot reach the seat of the fire; and may find themselves victims of the poisonous fire gases, thereby compounding the problem for the OIC.



With the commencement of an aggressive interior attack with preconnected hoselines, there must be timely consideration by the OIC of positive, adequate water supply. Pumps should be placed on strategic hydrants, using large diameter hose from hydrant to pump, or pump to pump, keeping in mind the total flow available from the water mains in the vicinity of the fire. Where municipal water sources are not ample, or available, prefire planning will indicate where static sources are available, and what tanker shuttle and large portable folding tanks are available.

Offensive interior operations require a primary search be carried out by the first arriving companies, using self-contained breathing apparatus. Definite areas of search and responsibility must be defined and assigned, and feed-back of progress must be communicated from interior companies out to the Command Post. According to the size of the incident, emergency medical services should be provided on the fireground for both civilian and firefighter casualties.

When fireground conditions permit, a secondary search of the fire building should be instituted, searching all affected areas and utilizing a company in the secondary search in an area different than the area they covered during the primary search.

The need for an ongoing size-up cannot be over-emphasized. The OIC must continually evaluate the operations and react to changing conditions. In some instances, the OIC can get a better "feel" for conditions by looking the situation over from a distance, rather than becoming intimately involved with the placing of lines, throwing of ladders, or in general terms, supervising every operation. His Command Post must allow him the best vantage point from which to coordinate and control fireground operations.

DEFENSIVE STRATEGY

Our primary objective on the fireground, beyond that of life hazard, is to deploy our resources so as to prevent further spread of fire, and a fast, aggressive, interior attack is the most effective route to successful fire control. It is this offensive action that, properly executed, will surround and confine a fire. However, there are many instances when the Officer-in-charge must select a Defensive Mode of operations.

Initial size-up may indicate to the OIC that fire has an overpowering control on the building, and/or there is a threat of potential structural collapse. Under such conditions, the decision must be made to resort to an exterior attack with outside streams - a defensive approach. The OIC must first, under these conditions, be willing to write off such a structure, and divert efforts to restricting further spread to other buildings. His size-up must be centered on evaluating fire spread, and deciding on where the key tactical positions will be located.

These tactical positions will depend generally on the direction and intensity of the wind, plus the location, proximity, and size of exposed buildings. His plan of action must be based on a <u>surround</u> and <u>confine</u> concept.

Under the defensive mode of strategy, heavy stream appliances are most often the initial means of water application. When these appliances are used, water supply becomes a vital factor in the planning process. The OIC should have the insight to project the possibilities and probabilities of the fire problem confronting him, and, given adequate apparatus and manning, implement suitable steps to give the firefighting team an upper hand. This is often difficult, and even impossible, but an early establishment of adequate water supply will begin operations on the right foot. Again, pre-planning of water sources will help the officer with this step of the decision process, and allow him to continue smoothly on to his next priority.

The fire officer must be aware of not only the water supply available from municipal and static sources, but just as important, the capacity of the hose layouts used by apparatus. If the defensive mode is chosen, hose layouts will have to be adequate for supplying appliances; length of lays and size of hose and nozzles will determine the maximum rate of application that can be used. Therefore, officers, as well as driver/operators, must be familiar with the carrying capacity of the different size hose used, as well as the hose loads carried on apparatus. As an exaggerated example, if the first due engine company lays a single 2½" or 3" feed line coming in, the OIC cannot then expect that company to supply a heavy stream appliance without making adjustments to the supply layout. WHEN ORDERING HEAVY STREAM APPLIANCES, THOUGHT MUST BE GIVEN TO ADEQUATE SUPPLY.

Perhaps one of the toughest decisions an officer must make under a borderline situation, is to abandon the offensive mode in favor or a strictly defensive attack. Under such conditions, the officer must remember, not only the capabilities of his men, but also that initial setting up may take many minutes before actual water application. The officer must realize this time factor involved, and when selecting a position for the heavy stream, attempt to analyze where the fire will be when water is ready to be directed onto the fire. He may commit to some type of holding action by one one

company while appliances are being set by another, or others. More often, however, the defensive mode will be an obvious choice, dictated by rapidly deteriorating fire conditions, and all hands will be deployed in an all out defensive stance.

The decision to adopt defensive actions is not restricted to initial operations. After an offensive attack is begun, for one reason or another, the attack may lack progress, or deteriorate. If the continuing size-up indicates that interior conditions, once an attack is started, are too hazardous, the OIC must alter the attack and shift into the defensive mode. Under these conditions, interior firefighting forces and lines must be withdrawn, and firefighting efforts directed from the outside. Withdrawal may even have to be done without lines

NOTE: Since withdrawal may have to be exercised with considerable haste, consideration should be given to a common signal for such action. An alert such as five blasts on an air horn, or a special tone for portable radios, may communicate to interior crews that immediate evacuation is necessary.

Often too, conditions may be encountered that call for both methods simultaneously. When conditions on arrival are at a border line stage, the officer may elect to institute an offensive attack, while setting up a defensive backup. The backup may never be used, but in the event the offensive attack fails, little if any time will be lost reverting to the defense.

LINE SELECTION

In the sequence of decisions that OIC must make, one of the most critical, and sometimes difficult, is selection of the proper size hose for initial attack. Difficult because, like other tactical factors, there is no formula, or even reliable rule of thumb that provides a quick, workable measurement for fireground use.

In order to select the proper size hose line for a given fire situation, the officer must have a good understanding of the rate of application of the various size nozzles; the rate of heat absoption; as well as basic hydraulics and protection capabilities of the various stream patterns. Factors that will determine an officer's choice of line size will include:

- A. Knowledge through
  - 1. Training
  - 2. Experience
- B. Size and intensity of the fire
- C. Rate of application required
- D. Stream pattern necessary
- E. Water supply available

KNOWLEDGE THROUGH TRAINING. Training must be directed towards improving performance, It is through repetitive company drills that an officer learns how much time it will take to perform each evolution. Whether it is advancing a 1½" preconnect, or putting a heavy stream appliance into operation, the officer must know his company's performance level. If the officer has confidence in his men, he will not hesitate to use good, aggressive tactics, Performance training will lead to timely decisions on the part of the OIC, based on confidence.

KNOWLEDGE THROUGH EXPERIENCE. Firefighting at the recruit training level involves live fires for a number of reasons, among which is to build confidence, and to learn the capabilities of various flow rates. It is this experience through training that will serve the firefighter under actual conditions. Knowledge will develop proportionately with the number of experiences the individual has to see the practical application.

When 1½" preconnect lines first began being implemented, fire departments were actively involved with live fires in vacant and abandoned buildings, to learn the capabilities and limitations of the 100 GPM nozzles. Confidence was built on the positive results wirnessed at these test fires. Since officers are most apt to go with a decision with which he is comfortable, based on past practice, it is training and experience that provide the foundation for sound decisions regarding line selection.

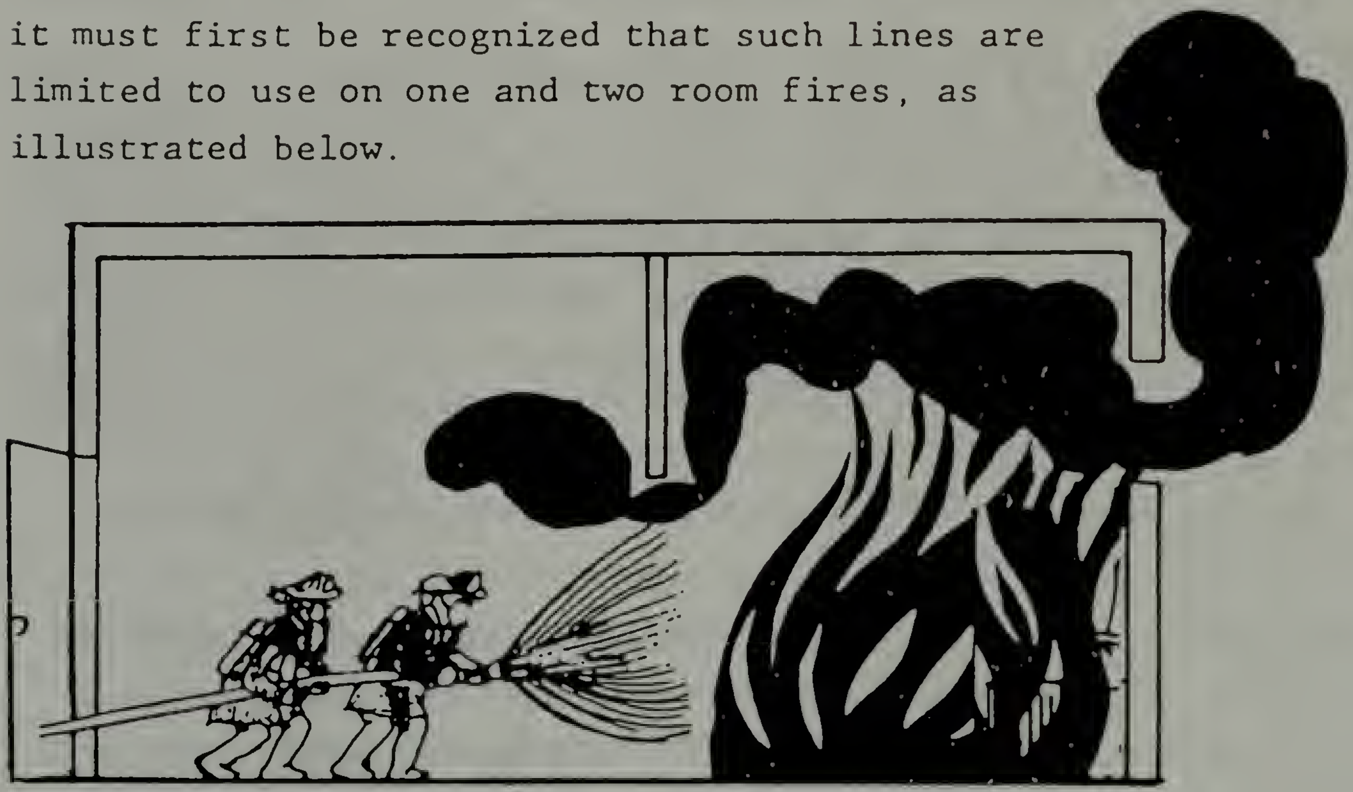
SIZE AND INTENSITY OF THE FIRE. The OIC must select the size hose and nozzle combination that will allow him to place the stream in the most advantageous position to cut off the fire from threatened occupants and exposures, to facilitate rescue, and to accomplish this with the manpower available. The line selected must effectively discharge an appropriate volume of water to knock down the fire. In other words, the flow capability of the nozzle should be compatible with the flow capability of the hose line. Thus, a 1 1/4" solid bore tip with 300 GPM flow is the largest recommended for a 2½" handline.

When judging the size line needed, consideration must be given to where the fire is now; where the fire may be after the line is placed in operation; and the volume of fire anticipated later into the operation. If the officer selects a deck gun as his initial attack, he must consider the time reouired to set up a heavy stream appliance. During this set up time the fire may have progressed to a two gun fire, whereas, if the original decision had been to go to a more speedy 2½" preconnect, the fire may have been stopped where the department found it. It is experience and training, again, that provide the best basis for such decisions.

Caution must be mentioned at this point concerning the tendency to automatically call for the most often used hose line, such as the 1½" preconnected line. If the situation looks bad on arrival, or appears to have potential, go for the big line. A big line can be used effectively to blitz attack a volume of fire, and later be reduced to a small line extended from the nozzle tip for final extinguishment and overhaul.

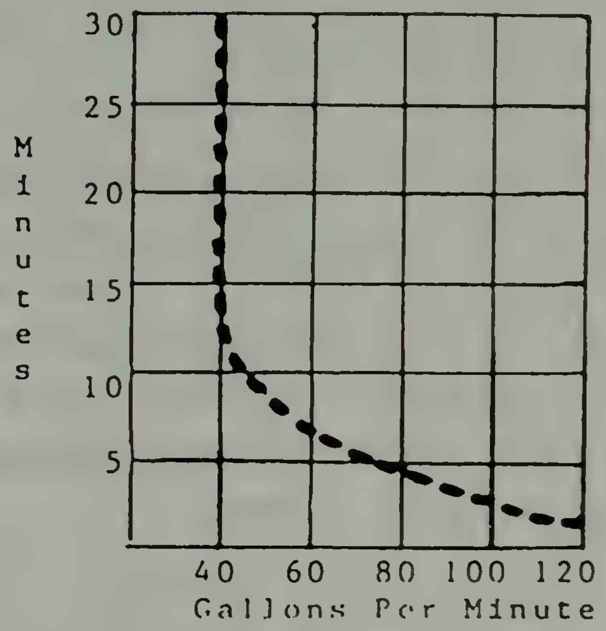
RATE OF APPLICATION REQUIRED. Although the flow needs to be at least that required to knock down the fire, it does not need to adhere to an exact gallonage, based on formula. As an example,

the flow from a 100 GPM combination nozzle may be used effectively to knock down a fire that also may be used effectively to knock down a fire that could be controlled by a 50 GPM combination nozzle. The knockdown time and point of shut off will simply be quicker with 100 GPM. However, if the decision were reversed, the fire would probably not be knocked down, and more likely extend. To further explain the capabilities and limitations of 1½" attack lines, it must first be recognized that such lines are limited to use on one and two room fires, as illustrated below.



The graph below illustrates results of a series of fires, with, as close as possible, the same heat generation in each fire at the time of initial application.

As shown, an application of 120 GPM extinguished the fire in two minutes, 100 GPM in three minutes, etc. Note that as the flow rate applied decreased, knockdown time increased until a flow application of less than 40 GPM did not accomplish extinguishment.

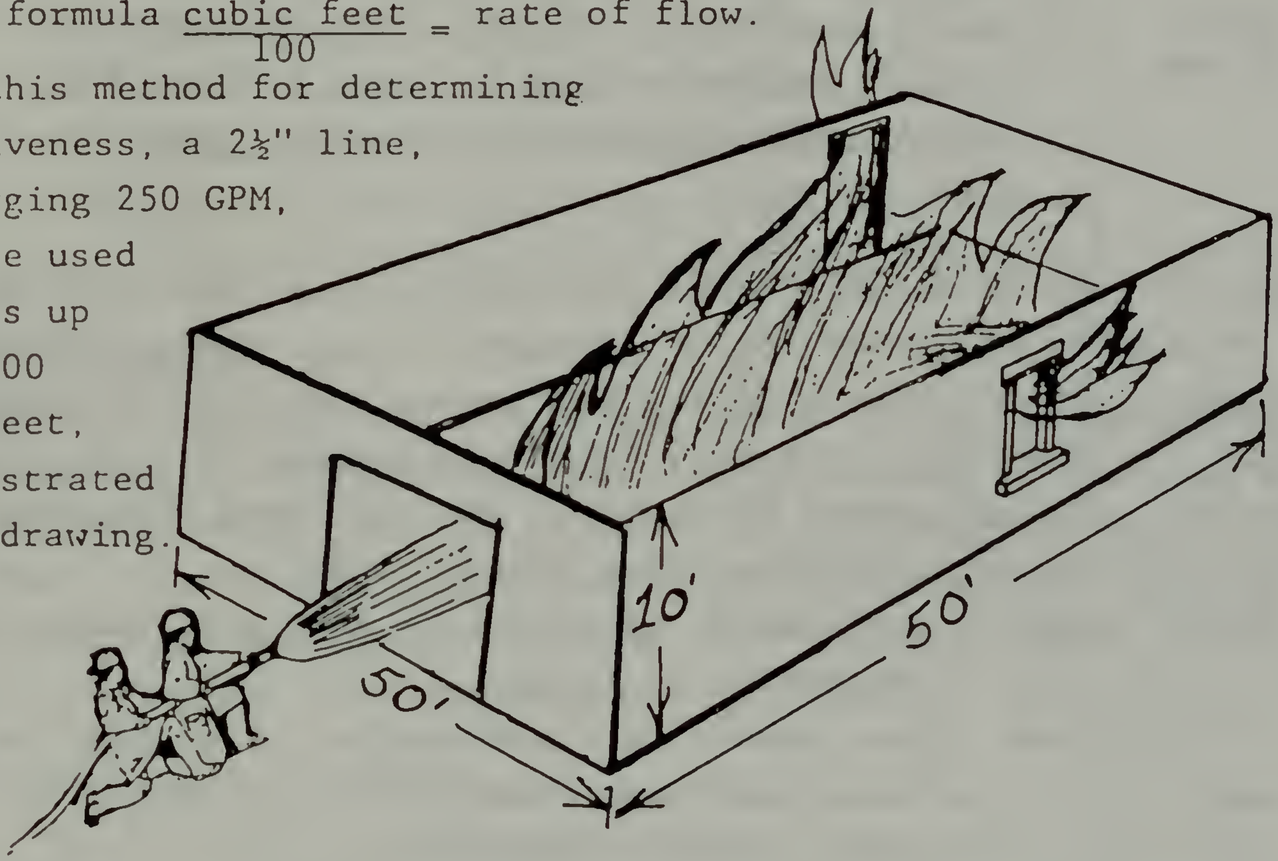


The OIC must always give consideration to back up lines. Particularly when the initial attack line is 1½", and there is considerable heat generation, a back up line should be provided as soon as conditions permit. This back up

shall be of at least the same size, preferably one size larger. If the OIC can't make up his mind between a small line or a large line, and decides in favor of the smaller, the fire may overpower the line, extend, and force retreat unless back-up is in position. WHEN IT LOOKS LIKE A BIG LINE JOB ON ARRIVAL - USE IT.

Analyzing the effectiveness of 2½" attack lines, some authorities suggest such a line can be used in areas up to 1000 square feet as a rule of thumb. However, another concept is the use of the of the formula $\frac{\text{cubic feet}}{100}$ = rate of flow.

Using this method for determining effectiveness, a 2½" line, discharging 250 GPM, could be used in areas up to 25,000 cubic feet, as illustrated in the drawing.



Under conditions as shown, the initial attack line must be backed-up, with either another 2½" line or appliance.

In most cases where master streams are used from the outset, fire is obviously beyond the capability of a 2½" hand line. The OIC should also, however, consider the use of appliances on the borderline cases, as with the Blitz Attack described under Water Supply. A fast application of water by a master stream may effectively hold the fire until handlines can be brought into position. A master stream discharging 500 GPM in a fog pattern, properly positioned. can absorb "X" number of BTU's in one minute, whereas a 1½" line, discharging 100 GPM will take 5 times as long to put the same amount of water on the fire and yet not absorb as many BTU's.

Consider the following characteristics of fire streams:

- 1½" lines - Fast application, mobile inside line, average volume of 100 GPM. Combination fog/straight stream available.
- 1 3/4" - Also fast, mobile attack capability for interior attack, volume range between 90 and 200 GPM, variable pattern selection
- 2½" lines - Slow, less mobile, fast knockdown, average volume of 250 GPM. Quick Blitz capabilities.
- Master Stream - Mostly stationary, multiple lines needed for supply, maximum volume of water. Quick Blitz attack when operated directly from apparatus water tank.

STREAM PATTERN NECESSARY. Since all nozzle sizes today provide the capability of either fog or straight stream, the pattern necessary will not have a direct bearing on the size of the line. However, considering the heat generated, together with the construction and arrangement of storage, the following characteristics of fire streams must also be taken into account:

- Solid Stream - good reach, penetration, wind resistance, less conversion to steam.
- Fog Stream - Less reach, less penetration, poor wind resistance, good heat absorption and conversion to steam. Good shielding.

WATER SUPPLY AVAILABLE. There will be situations where the water supply available will not support the intial attack lines that should normally be selected for the conditions on arrival. Particularly in rural areas, initial attack may require a defensive stand until additional supply can be secured through tanker shuttle or hose relay. Even in urban areas, the municipal water supply in the immediate area of a moderate to high value district, may not support an adequate initial attack. In such cases, line selection will follow a pattern to support a "holding" position, until supplemental sources can be obtained.

An interesting theory worthy of note is that it is better to have nozzles attached to lines on the apparatus prior to the fire than to make necessary the attachment of such nozzles to hose lines under fireground conditions. This theory is based on the

fact that it is easier to take an appliance apart at the fire scene under stress than it is to make up threads.

CHOOSE YOUR LINE BASED ON AN OFFENSIVE ATTITUDE WHERE THE NOZZLEMAN WILL BE THE AGGRESSOR, NOT THE FIRE.

FRICTION LOSS COMPARISON (PER 100' OF HOSE)				
FLOW	1½"	1 3/4"	2"	2½"
100 GPM	30 psi	15 psi	5 psi	--
125 GPM	50	25	10	2
150	--	30	15	5
200	--	60	25	10
250	--	--	45	15
300	--	--	60	20

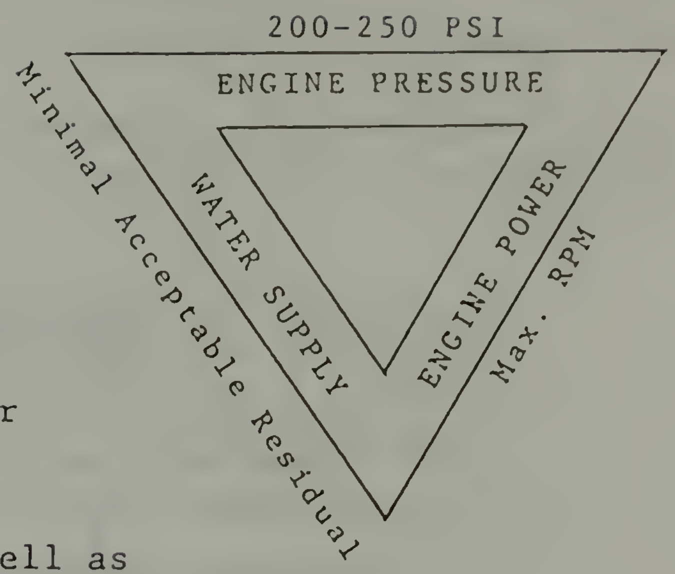
AUTOMATIC NOZZLES

The trend in the fire service today, due to austerity programs, is toward having to do more with less. Water supply is one area which fire departments may look to in order to positively reenforce their adjustment to depleting resources. Automatic nozzles, especially when used in conjunction with 1 3/4" or 2" attack lines, are providing departments with greater capability on the fireground.

In a survey done for Fire Chief Magazine, users were asked "Has the automatic nozzle accomplished for your department what you hoped it would?" Response was overwhelmingly in favor, indicating automatic nozzles not only have a beginning, but a healthy future.

The operating principle of the automatic nozzle is based upon an elastic hole; one that gets bigger or smaller by itself in response to changing flow conditions. The automatic nozzle constantly senses nozzle pressure, changing size quickly and accurately, exactly as necessary to regulate a constant nozzle pressure for itself. The nozzle, designed to provide a good stream, maintains a pressure at approximately 100 psi throughout its range of flows. In theory, a pressure-sensitive divice, located in the nozzle assembly, constantly gauges the flow, and automatically passes more or less water in accordance with what is available, similar to a relief valve on a pumper.

The simplified auto-hydraulics of the automatic nozzle can be easily remembered as a "Water Triangle". Each side represents one of three limits to any pumper setup. Working the pumper to whichever of the limits is reached first produces the maximum possible flow for that particular layout.



Although there are disadvantages as well as advantages to their use, generally, the automatic nozzle will increase the GPM delivery per firefighter and reduce the effort required to deliver the increased flow.

LINE PLACEMENT

Selecting the proper location to commit various hose lines is predicated upon many fireground variables that will often change from each and every situation. Certain procedures, however, can be incorporated as standard operating procedures.

Generally, for a strong offensive attack, the first handline should be advanced inside the fire building to attack the fire from the unburned side. Where there is a life hazard involved the line must be placed between the fire and those persons endangered, with the commitment to control access to hallways, stairways, or other areas where people may travel to escape the fire. Where there is no life hazard involved, the first stream must be placed between the fire and the most severe or immediate exposure.

Additional handlines must be placed to cover secondary means of escape; to provide back-up support for the first line(s); or to cover endangered internal/external exposures. The order of placement of these additional lines must be prioritized by the Officer-in-charge, based upon immediate conditions as they present themselves. The placement of hoselines to cover the above mentioned areas will depend upon, among other things, the manpower available to stretch and operate the line; the mobility of the line (1½" or 2½"); the water supply immediately available (hydrant supply or tank); and the speed with which the line can be placed to buy time for rescue efforts, etc.

Place the line to achieve immediate results and with consideration toward repositioning that line to accomplish additional tasks with minimal shut-down time and maximum water application time on the fire.

Placing the line may involve sacrificing good tactical procedures in order to gain time to achieve an immediate goal. If good tactical procedures are temporarily sacrificed, position a secondary line to back it up.

Most often, the company that places a line will stay with that line, unless the situation drastically changes. Therefore, good

procedure would dictate that the line selected and positioned would be that one that would handle the fire from initial attack to time of overhaul. If the fire warrants a large volume of water from a handline, and the manpower is available, and the position is advantageous, use the big line. Beware of using the line that is most often popularly used - select and position the one that is actually required.

Where a fireground situation on arrival is beyond the offensive attack stage, and a defensive or holding action must first be instituted, placement of a line or lines will be to hold the fire to the building or area of origin with the thought of managing the fire until an offensive action can be started.

A defensive operation commonly involves the employment of heavy stream devices, deck guns, or ladder pipes from an exterior location. Place the heavy stream in a position to cut the fire off and contain the burning area, not in a position where the device is wetting down an area that has already been destroyed. Consider where the fire may be when selecting this defensive position in terms of how much time it will take to achieve the position and actually apply water.

Generally speaking, heavy stream devices will give more effective knockdown results than many individual handlines. If the OIC opts to the exterior streams, the stream must be large enough, preferably with a straight or open bore nozzle tip to get good reach and penetration with minimal wind interference. Do not operate exterior large calibre streams into buildings where no fire is visible. If the stream is not achieving the desired results after it has been operating in the same location for a period of time, shut it down, or reposition the stream.

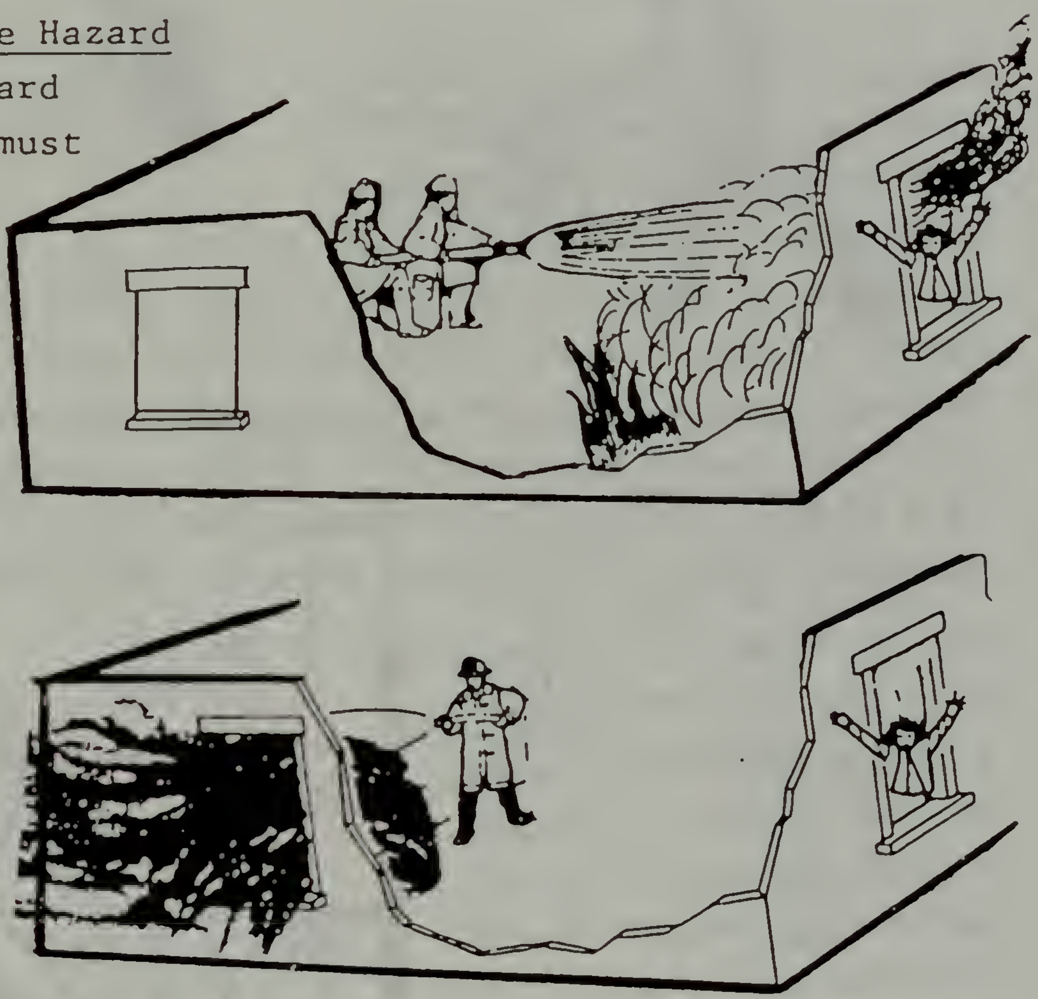
Ventilation holes, spewing forth smoke and hot products of combustion offer a tantalizing location for misplacing a hoseline. Ventilation points allow smoke, heat, and fire to escape upward and allow hose line crews to come in at the base of the fire to effect extinguishment. DO NOT OPERATE LINES DOWN INTO VENTILATION HOLES. Ladder pipes operating down through a roof opening also, often violate the natural upward flow of products of combustion.

Occasionally, a fireground situation may dictate placing a line or lines uncharged in anticipation of fire spread to an unburned area. Consider the placement of these defensive lines to insure immediate attack if conditions deteriorate and the availability of secondary water supply sources for these precautionary lines.

When ordering line placement, the OIC should follow a thought process that prioritizes evolutions in accordance with the Order of Operations.

<u>Priority #1 - Protect Life Hazard</u>

Where there is a life hazard involved, line placement must not be made in a manner that will push heat, smoke, and gases toward those endangered, further threatening their position. Instead, inital line placement must be between the fire and those persons endangered by the fire, with a commitment to control access to hallways, stairways, or other areas where people may travel to escape the fire.



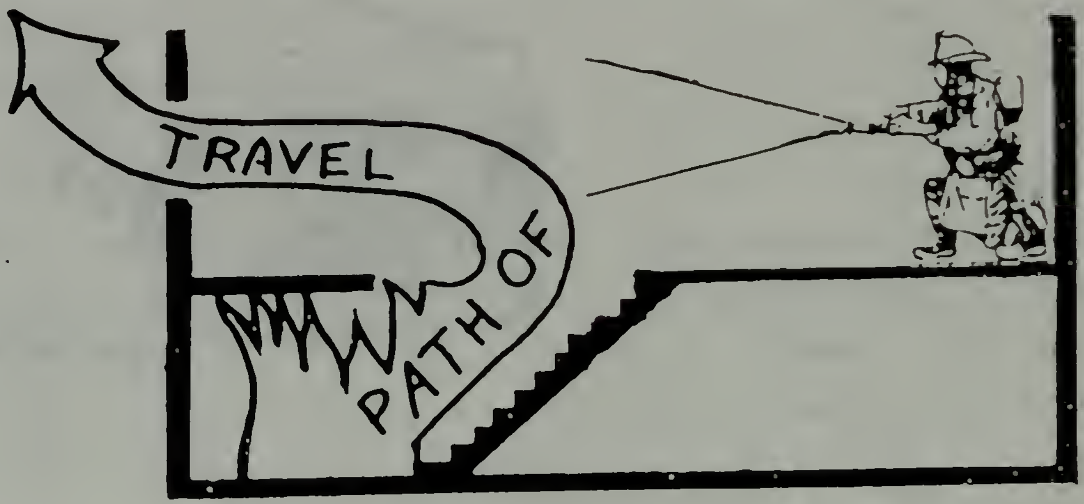
<u>Priority #2 - Protect External Exposures</u>

Once the OIC is satisfied the life hazard is either not apparent, or has been accomplished, he must consider the threat of the fire building to other structures. Overlapping fire in a conjected neighborhood presents an obvious potential that the OIC must recognize at once, and react to appropriately.

When positioning and directing lines to cover external exposures, it must be remembered that radiant heat is capable of penetrating fog streams. It is therefore essential, for proper coverage, that such streams be applied ON the face of the exposed structure.

Priority #3 - Extinguishment

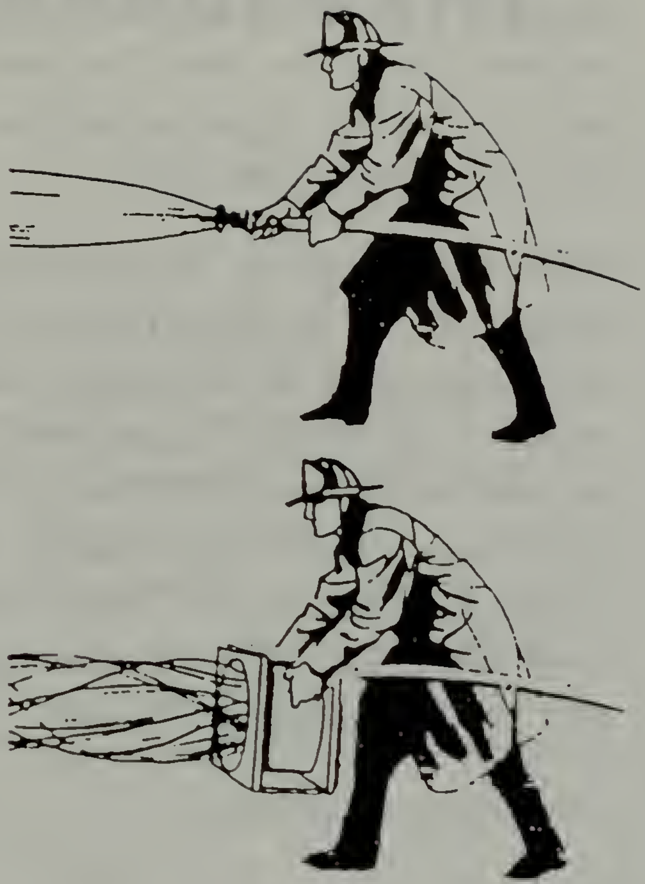
Previous knowledge and experience of fire behavior will provide the officer with a basis for determining rate and path of travel. Path of travel is that route, dictated by the natural flow of heat, smoke, and gases via convection currents, channelled by the building features. Timely, effective ventilation will be a primary factor in directing the fire up and out of the building through a selected channel, with minimum extension.



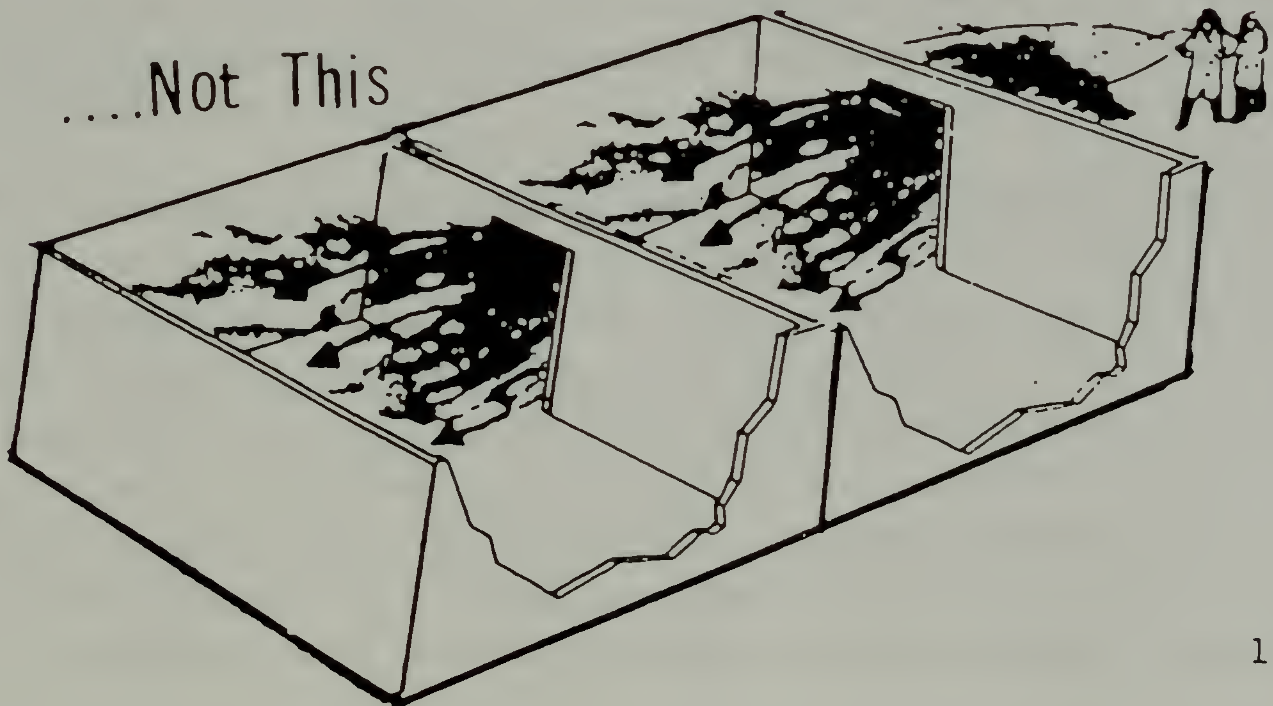
Often, however, fire has reached a stage where it has self-vented horizontally or vertically to the outside, and established its own path of travel. Under either of these conditions, two general principles should be adhered to if possible.

A. The chief factor that will influence the path of heat flow will be structural features. If the OIC, during size-up, is able to determine that an acceptable flow route has been established, he must avoid disrupting that flow. It must be remembered that hose lines are capable of pushing fire in the direction in which they are pointed. We only have

to return to the Ventilation section to review the effectiveness of fog patterns as smoke ejectors, and realize that nozzles are capable of moving considerable amounts of air as well as water. In fact, studies have shown that fog nozzles are capable of moving more air than ejectors. It therefore becomes imperative that officers think of nozzles as having the same capabilities as fans, and will PUSH FIRE. Hence, the OIC, when positioning lines, must ask himself if his choice will push fire the way he wants the fire to go.



B. Approach the fire from the UNBURNED SIDE. When no life hazard to occupants is apparent, the first stream must be placed between the fire and the most severe or immediate exposure. Generally, for a strong offensive attack, the first



handline should be advanced inside the fire building to attack the fire from the unburned side. Such an approach will, if line size selection has been adequate, prevent further spread of fire.

Training leads to self-discipline. It is discipline that helps us to deviate from any instinctive urge that will lead to unpleasant or unwanted results. Instinctively, under stress conditions on the fireground, there may be a tendency to want to put water on the fire quickly from the most easily accessible position. Such a tendency, or urge, has been described by Chief Brunacini in "Fire Command" as the "Candle Moth Syndrome"- that behavior that causes tunnel vision, and directs our attention to flame hypnotically.

FIRE STREAM MANAGEMENT

It is the objective of every fire department, once any threat to occupants has been addressed to the satisfaction of the OIC, to efficiently gain control of the fire. Such control will depend, to a great extent, upon the degree to which the OIC is able to exercise control over fire stream placement and management. The OIC must keep in mind that the effectiveness of fire streams will be directly influenced by the coordination of supportive activities, whether the scale of operations is a one 1½" attack or multiple 2½" attack. The speed of attack, for example, and the application of the fire flow from nozzles, will depend on the entry capability of attack crew(s), which depends on the timing and amount of ventilation accomplished. The success with which entry is gained and the amount of necessary laddering that can be quickly accomplished will also influence the speed of application.

Fire control is often influenced by the technique of nozzle operation and movement. The nozzleman, therefore, frequently becomes a primary factor in the "quality" of control. It is his training, experience, and judgment that will contribute positively to command level tactics. It should be recognized that, although planning and practical training may be centered around an officer and firefighter together on each attack line, under fireground conditions, the firefighter may be alone handling the line. In either case, the OIC himself will not be able, nor should he attempt, to personally supervise the operation of each stream, particularly interior streams. Therefore, he will depend heavily on the training his officers and men have received to guide them in the use of such streams in a manner that will, through proper application techniques, contribute toward a coordinated fire attack.

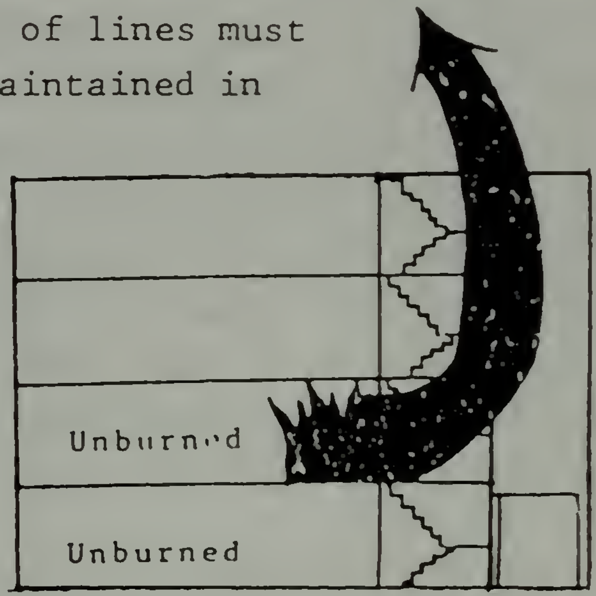
Before further discussion of the techniques for stream application and management, two basic points must be stressed that will directly effect the ability of attack crews to function effectively, with the capability to react to sudden changes in conditions:

1. Full protective clothing and self-contained breathing apparatus must be worn by all personnel involved in interior firefighting operations. Without such equipment personnel may not have the capability to reach the seat of the fire and remain in position long enough to perform their assigned task.

B. Before performing horizontal ventilation, and before entering a hostile environment, water under adequate pressure must be supplied up to the nozzle of attack line(s). This does not eliminate the suggestion of stretching uncharged lines over stairways, fire escapes, or ladders to reach the fire area. It is, however, intended to suggest that charged lines be provided to equip attack crews with the capability to react to rapidly changing conditions that might develop quickly during the setting up stage of operations in a fire area.

Listed below are some basic points of fire stream management that must be considered by the attack crews operating hose lines.

1. During an offensive attack, nozzles should not be opened until the fire is found. Attack crews must be disciplined to the fact that the promiscuous directing of streams into smoke is generally not effective firefighting, but rather, hit or miss firefighting that simply contributes to excessive property damage.
2. As discussed during Line Placement, the most important factor relating to the effective direction of streams is establishing at the outset, a proper direction of attack in relation to internal exposures and path of fire travel. It therefore becomes critically important during stream management to maintain some semblance of proper direction of attack during continuing operations. During attack, the mobility of lines must be such that proper positions are maintained in accordance, when possible, with the intention of approaching from the UNBURNED SIDE. Operations at the company level must continue toward an awareness of the path of fire travel, and the effect of stream(s) on the desired path of fire travel and its extinguishment, as indicated on the accompanying sketch.



3. Maintaining communications will be vital to the OIC. In the case of interior lines, progress at the company level must be periodically fed out to the Command Post in order that the OIC can analyze overall operations.
4. During interior firefighting, nozzle shut down must be coordinated with fire knockdown to eliminate unnecessary water damage.

Training and experience provides the nozzleman with the ability to recognize when the atmosphere has been cooled down sufficiently to limit further water conversion for extinguishment. The nozzleman must recognize, at this point, further application must be directly applied to the burning materials.

5. Training and experience will also provide personnel responsible for nozzle operations with an understanding of the Direct, Indirect, and Combination methods of attack. The nozzleman must be capable of sizing up the conditions he is confronted with upon entry into the fire area, and, upon evaluation, select the proper method of attack that will best accomplish desired results.

METHODS OF INTERIOR ATTACK

Effective extinguishment depends on quick transfer of heat from the involved materials to the water being applied. Consideration, therefore, must be given not only to the proper break-up of streams into a form that is most conducive to rapid absorption of heat, but also to the method of application.

Direct Attack. When fire is found in its earliest stage, with minimal amount of material burning, and heat conditions at levels that permit approaching attack crew to get close to the flame source,

a DIRECT ATTACK will obtain best results. It is this type of fire that constitutes the majority of structure fires; those where a crew with a hose line can reach the seat of the fire quickly, ventilate, and extinguish by applying water directly onto the fire. Under such conditions, it is the Direct Attack that results in minimal structural damage and water damage.

INDIRECT ATTACK. The earliest references to Indirect Attack are found in "Attacking and Extinguishing Interior Fires", by Lloyd Layman, published by the NFPA in 1952. In his text, Layman describes the Indirect Attack as a removal of heat from the burning structure by the conversion of water fog to steam, reducing the temperature below 300° F. The results of the Indirect Attack are twofold: First, the reduction of the ambient temperature in the fire room via heat transfer from the conversion process of water to vapor within the fire area, and secondly, the expansion of the steam produced, and the resulting smothering effect such steam creates in the fire area. The steam fills the combustion spaces, forces its way out of these spaces, extinguishing surface fire as it travels due to unvaporized water contained in the steam.

NOTE: Indirect Attack should not be confused with indirect results. Convection currents may cause steam, generated at lower levels, to be carried upward, resulting in limited extinguishment at upper levels.

During the days of early experimentation with fog, it was recommended that the Indirect Attack be made from the exterior of the structure. Modern techniques, however, recognize that unless the building is untenable from either heat conditions or structural instability, the attack should be made from the interior, unburned side. Nevertheless, the interior Indirect Attack is currently based on principles set forth by Layman.

Fire conditions that suggest the use of Direct application are those where application of water on burning materials will not seriously disrupt thermal balance. Fires that have reached the next stage of development, however, where fire is mushrooming across the ceiling, present another challenge, and may require a different method of attack. Often in the immediate area of a free burning fire, visibility is not a problem initially. The task for the nozzle crew becomes more complex, however, if the application method so disrupts thermal balance that smoke, steam, and products of combustion completely obscure vision. Upon further entry into the fire area, orientation of personnel may then become extremely difficult for final extinguishment and ventilation. The primary advantage of the Indirect attack is, if properly executed, to maintain thermal balance, thereby providing a tolerable level of tenability and visibility.

Basically, the hose line is advanced into the fire area to a position as close as possible to the point of greatest heat concentration. The key to Indirect Attack is proper nozzle operation. With a nozzle setting at wide angle pattern, the pattern is directed vertically and operated for a short duration. Time of application will vary with the size of the involved area. A 5 to 10 second burst may suffice for a single room, or 15 to 30 seconds for larger areas. (If more than several 30 second bursts do not reduce the volume of fire, the flow rate is insufficient.)

Proper application of the Indirect Attack is designed to minimize the disruption of the thermal balance, thus maintaining visibility and the tenable environment at floor level. Although a wide angle setting may be effective for most fire situations, the pattern setting may have to be adjusted in accordance with the width and height of the fire area. As an example, a wide angle application in a hallway will only hit the walls, not effectively reaching the ceiling. Or, in cases where the thermal barrier is low, the nozzle setting may have to be narrower for the purpose of effective extinguishment and tenability. The stream pattern, therefore, has to be set to conform with reach needs.

Once the bulk of heat has been knocked down with overhead application, an aggressive Direct Attack is made on residual fire in contents or concealed spaces in order to complete extinguishment. Ventilation must be timed to occur as Direct application is begun. (If the fire area is inaccessible due to heat level, ventilation may be required prior to initiating Indirect Attack.)

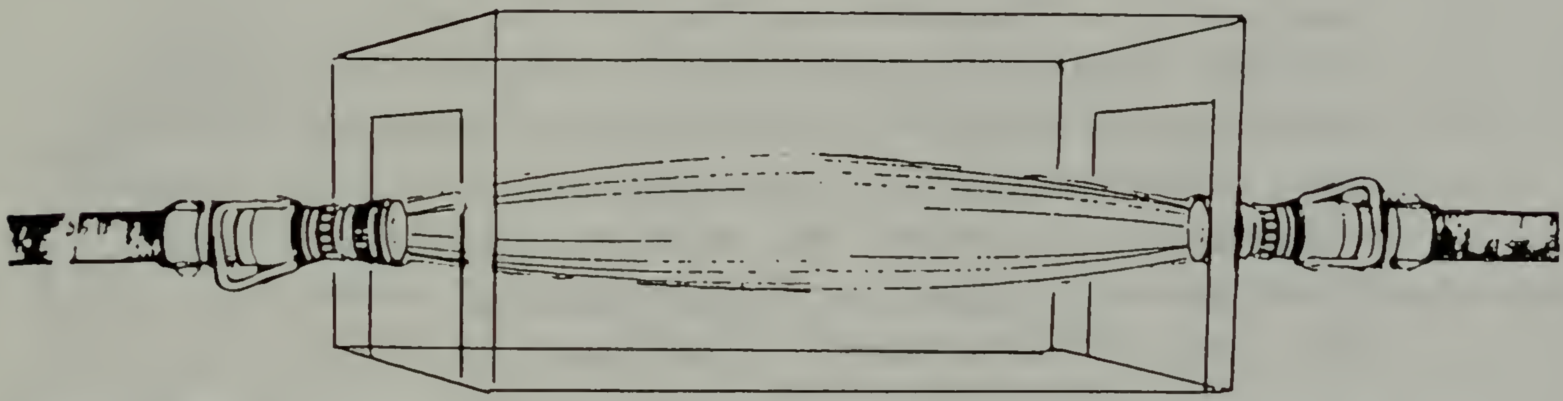
COMBINATION ATTACK. Under conditions where an area is fully involved, quick knockdown may require a sweeping motion of the nozzle, accomplished by a rotation in a clockwise direction. Such rotation will provide the fastest method of cooling the entire area. With the use of this attack method, and due to the large amount of steam that may otherwise be generated into a confined area, ventilation must be performed ahead of the fog nozzle. If the interior attack crew is not satisfied that ventilation has been accomplished at the

time of initial water application, short bursts from the nozzle will reduce the rapid build up of steam, as well as give some indication of the extent of ventilation performed.

From a broader perspective, and from the point of view of the OIC's responsibility, there are a number of factors that must be considered.

A. One primary example is the problem that may develop from opposing lines. Although streams should not, as a rule, be ordered into opposite ends of a building, there are instances where such practices are unavoidable, and even desirable;
   1. Opposing lines may be required under certain conditions, such as with large area buildings, and with fire spreading over a large area.
   2. If the OIC is relatively certain that interior division walls will prevent direct conflict between streams, opposing positions may be tolerated.

If, however, neither of the previously mentioned conditions can be assured, opposing lines may not serve effectively toward the best extinguishing tactics, and may even contribute to the injury of firefighters. At some point during the operation of opposing lines, there is apt to be a period when one line will



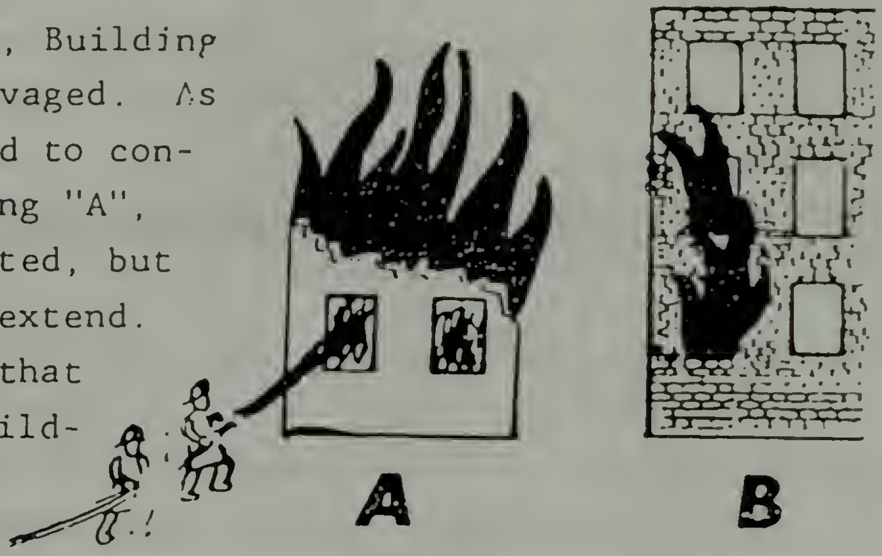
shut down and the other will push heat, smoke, and gases into the opposing crew. The movement of heat and/or super heated steam by the working line may create untenable conditions for the opposing crew, possibly resulting in needless injuries, regardless of protective clothing and breathing apparatus worn.

The OIC must take preventative steps to eliminate the possibility of these conditions happening. In order to reduce the conflict between streams, if conditions warrant the placement of streams at opposing positions, the OIC must remember to use acceptable practices that will not only contribute to reducing the possibility of injury, but will contribute to overall good tactics.

A. Communication between nozzle positions and the Command Post is essential for the coordination required for effective firefighting. Portable radios should be available for attack crews, and feedback of interior progress encouraged. It must be recognized, however, that interior crews, with required self-contained breathing apparatus, will have problems communicating through a facepiece into the portable radio, unless provision is made for microphone attachment that will permit mask to radio speaking.

B. Ventilation, as suggested by the Order of Operations, should be accomplished ahead of extinguishment, in cases of extensive fire where interior firefighting is to begin. Such ventilation will provide a path of relief for heat, smoke, and gases. Such contaminants may be pushed to the outside atmosphere, rather than in the faces of oncoming, opposing crew(s).

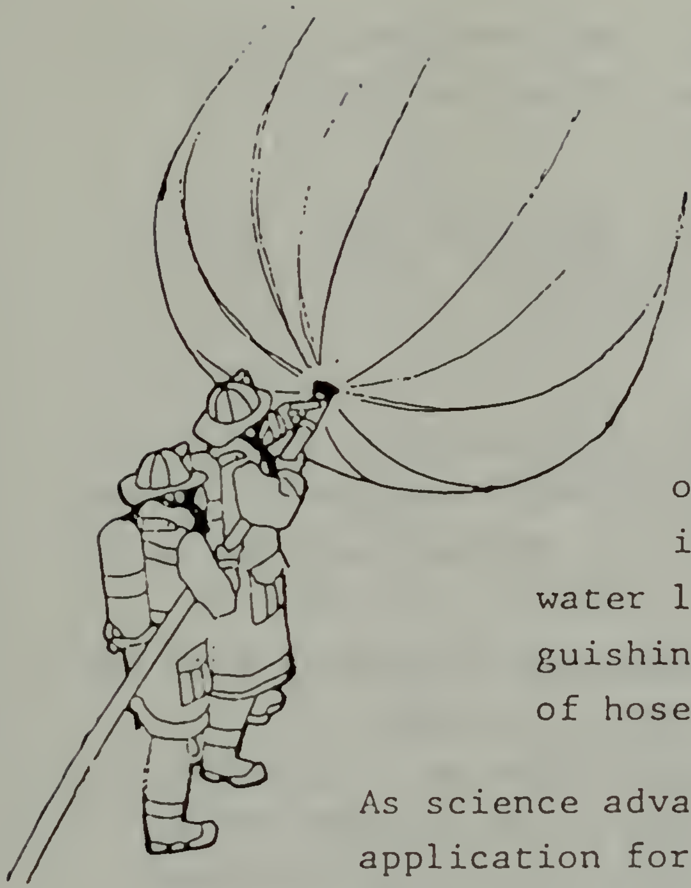
B. Another point for consideration by the OIC is the repositioning of ineffective lines. It has been noted, through thorough analysis of many fires, that there often is an inclination to position hose lines in selected, key positions on the fireground, and then continue to operate from the same position for extended periods of time, beyond the point of effectiveness. The OIC, as well as company officers, should pay particular attention to the need for occassionally shifting lines for better advantage on the fire. If the line has accomplished an appreciable amount of knockdown in the initial position, and can gain more effectiveness on the fire from an adjusted nearby position, such line should be moved or redeployed accordingly.



In the accompanying sketch, Building "A" cannot be saved or salvaged. As long as the line is allowed to continue to operate on Building "A", not only will water be wasted, but fire in Building "B" will extend. It is this same principle that applies to fires in one building, where a position of application is no longer contributing to extinguishment, but movement to another window or area may substantially increase attack results.

If operation of a particular line or appliance should be readjusted or shifted, but for one reason or another cannot, it should be SHUT DOWN. It cannot be overemphasized that water supply on the fireground is often a critical factor. Officers and firefighters alike must recognize that ineffective streams, among other negative contributions, serve to compound what may already be a depleted water supply. Shutting down of a useless stream can substantially increase the effectiveness of other streams in key positions.

THE USE OF FOG



Before considering methods of water application for extinguishment purposes, mention must first be made of the basic physical characteristics of water. Since history began, man has recognized the value of water as a cooling agent. The availability, cost, and heat absorbing qualities of water led to its acceptance as the primary extinguishing agent, in conjunction with the development of hose, nozzles, and pumps.

As science advanced, so has our understanding of water application for firefighting. As we gained more understanding of the combustion process and fire behavior, methods of water application improved. For centuries the straight stream was the primary form of application, splashing off ceilings and walls with limited absorbing power. Although the straight stream still has its function on the fireground today, research has indicated the advantage of application of water in spray form to be superior for interior fires.

Pioneers in the research of water application, like Lloyd Layman and Keith Royer, found that perfection in the use of water for interior firefighting would be achieved if water could be applied in a form, and at a rate whereby the entire volume would be converted into steam. Research further demonstrated the rate of heat absorption can be increased by increasing the surface exposure of the water - breaking the water into finely divided particles. Thus was born the fog nozzle.

HEAT PRODUCED AT FIRES

Normal air contains 21% oxygen. During the combustion process, however, when the oxygen level is lowered to 14%, open flame is arrested, although smoldering may continue. Therefore, for practical purposes, subtracting 14 from 21 leaves only 7% of the oxygen actually used to support combustion. Scientists tell us that one cubic foot of oxygen, united with fuel, will give off 535 BTU's

during the oxidation process known as fire. However, since only 7% of that cubic foot is usable during combustion, 7% of 535 leaves 37 BTU's of heat given off.

In a room 10' X 10' X 7', the volume is 700 cubic feet, and is capable of generating 25,000 BTU's (700 X 37).

FOG CAPABILITIES

When we look at the capabilities of the fog nozzle we find:

A. One gallon of water will absorb 1250 BTU's during the process of raising its temperature from 62 to 212 degrees, the boiling point.

B. This same gallon of water will absorb an additional 8080 BTU's during it conversion from liquid state to steam.

One gallon of water, therefore, absorbs 9,330 BTU's in the process of becoming steam. However, we must keep in mind that this is based on 100% efficiency. Realizing that this is not possible, we must use an effective rate and assume that 80% is probable. Using this figure, we determine that 9330 X.80 = 7464 BTU's per gallon of water applied. It is this information that further translates into the commonly used formula

$$\frac{\text{Cubic Feet of Area}}{100} = \text{GPM}$$

From these facts it can be seen that not only does the water, during conversion, cool the burning material down below its ignition temperature, but also generates steam. One cubic foot of water (7.5 gals), when converted into the gaseous state, will generate 1700 cubic feet of steam, and will create the following:

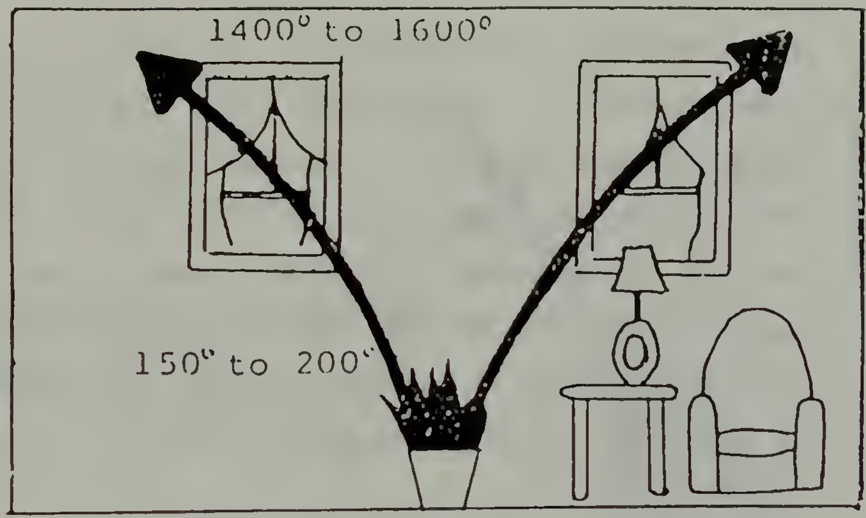
A. A temporary inert zone of steam in the fire area that will have a smothering effect on remaining fire. Upward and lateral convection currents may cause the steam to have a positive extinguishing effect on remote fire areas.

B. Expansion rate of steam will aid in ridding the fire area atmosphere of contaminants. During condensation, fresher air will be brought in, thereby aiding ventilation.

HEAT TRANSFER

The three types of heat transfer, conduction, convection, and radiation all have a direct influence on heat transfer and fire spread. Convection, however, is the method that most affects the

type of attack to be used with the fog nozzle. During a fire in its earliest stages, heat production will be localized around the point of origin. As fire progresses, convection currents increase, carrying heat to upper levels, until temperatures at those levels reach between 1400 and 1600 degrees. It is this stratification of heat that will determine the most efficient method of fog application. The three methods of attack using the fog nozzle are covered in the previous section, "Fire Stream Management".



THERMAL BALANCE

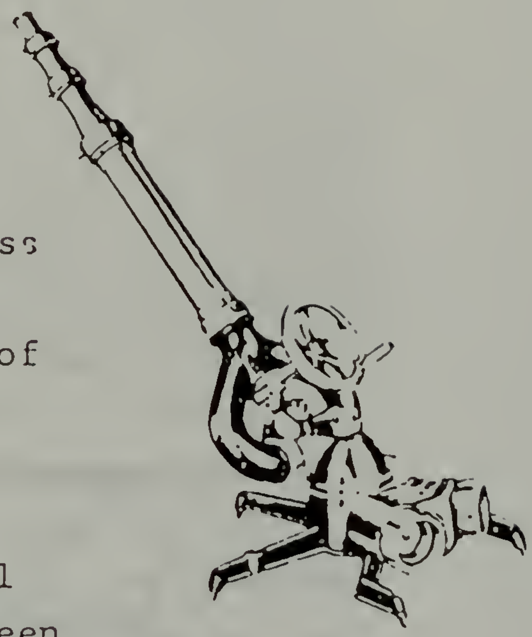
Firefighters occasionally encounter the fire scene where an interior attack is accomplished by using the Combination Method of application. During knockdown, convection currents are disrupted almost immediately upon initial discharge into the area, causing the upper thermal forces to be pushed downward, obscuring visibility. With the thermal balance disrupted, future operations such as overhaul are hindered.

Using the Indirect Method properly, thermal balance can be maintained throughout the operation, thereby enhancing operations. To accomplish this, the nozzle is adjusted to a wide angle setting before entering the fire area. Upon reaching the fire area, the nozzle is directed at the ceiling, and short blasts of approximately 5 seconds are discharged, lowering the temperature uniformly at all levels. With short blasts, the convection currents are not disrupted. As the area is cooled the attack team can advance on the burning materials using a Direct Method from short range while ventilation is being accomplished. Timing is essential on the part of the nozzleman, as is adequate training.

THERE IS NO SUBSTITUTE FOR A WELL TRAINED NOZZLEMAN.

In summary, the officer, as well as the nozzleman, must rem ber that water is only effective for heat absorption when cha. from liquid state to steam. In order to achieve this conversion, water must be applied into an area where the temperature is hot enough to accomplish this conversion. This undoubtedly requires aggressive, interior firefighting where the line can be directed onto the fire or super heated overhead. The promiscuous directing of streams into unheated smoke is not effective firefighting.

EFFECTIVE USE OF MASTER STREAMS



The term "Master Stream" refers to Deck Guns, Deluge Sets, Monitor Nozzles, and Ladder Pipes. The use of such appliances should be considered when:

1. A volume of water must be applied in excess of the capabilities of hand lines.
2. Reach is desired beyond the capabilities of hand lines, such as,
   a. where radiated heat prohibits close operations
   b. where collapse or explosion potential dictates establishing distance between personnel and heat source
   c. elevation is necessary above the range of streams from ground level.

Once the Officer-in-charge has committed his resources to a particular plan of action, it is usually quite difficult to make any rapid changes in those already committed apparatus, especially to heavy stream appliances. It therefore becomes critical that, because of their immobility, the positioning and use of master streams be carefully considered. The following list contains some guidelines for their effective use.

1. When using master streams, it is essential that an adequate water supply is provided. To take full advantage of such supplies, fireground operations should include:
   a. Pumps set at hydrants, connected via large soft suction in order to take full advantage of water main capacity
   b. Use of large enough diameter hose to move water distances
   c. Siamesing of lines to improve hydraulic effectiveness
   d. Care not to overtax water supplies
2. Varied size and pattern tips should be available where the gun or pipe is mounted, for quick changing or attachment.
   a. Stacked tips allow the flexibility of selecting the appropriate GPM, and provide a solid stream for ample penetration for the particular circumstances.
   b. Variable flow and pattern nozzles provide break-up of water for rapid absorption of heat.

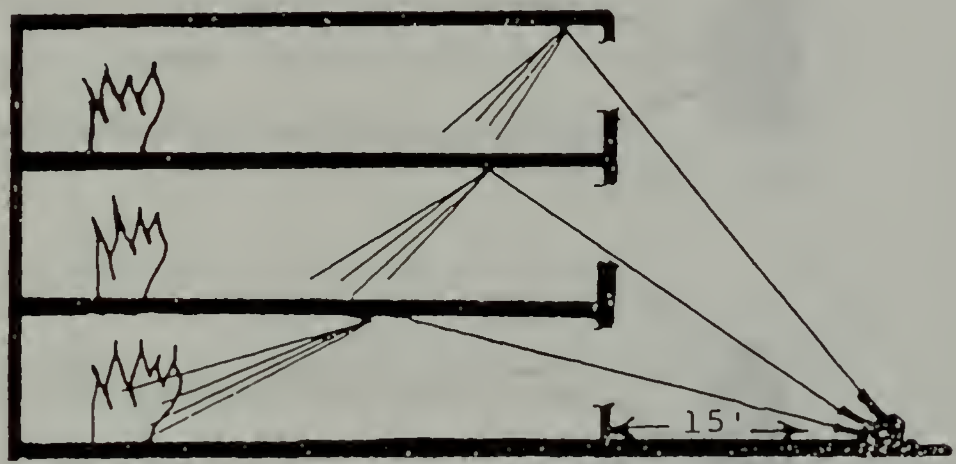
c. Discharge of appliance must be compatible with flow capability of the supply lines

3. In recent years, the fire service has recognized the heat absorption qualities of spray nozzles, and has incorporated various flow and pattern style nozzles for master streams. When spray streams are used on appliances, however, such streams may be rendered ineffective by:
   a. Wind conditions
   b. Thermal updraft created by fire
   c. Absorption and conversion by radiated heat, with little if any affect on extinguishment.
4. When master streams are needed, it is usually imperative that they be placed into operation as quickly as possible. Therefore, consideration should be given to pre-piping of guns and ladder pipes for key apparatus. The flexibility of guns should also be provided, allowing for the dismounting and portable use of guns.

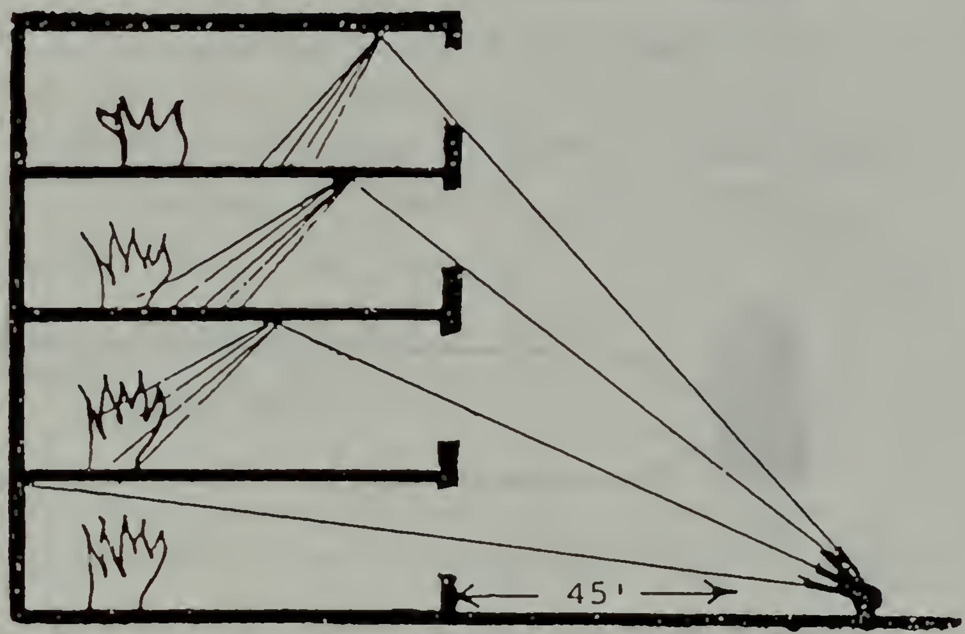
   Today's alloys have provided light weight appliances, that can be used from roofs, fire escapes, or other high vantage points of adjoining or adjacent buildings.
5. Under most conditions, one spot application of water should be avoided, As with any size stream, the stream should be shifted occassionally to get full advantage of application and heat absorption.
6. Another point that will help eliminate problems on the fire-ground is having all tips standardized for initial operations. Such a policy allows both officers and driver/operators to know in advance, regardless of what appliance they put into operation or support, the GPM will be the same for all. If the fire conditions warrant more or less flow than these tips deliver, such tips can be changed accordingly.
   a. The discharge from a 1 3/8" or 1 1/2" tip falls within the flow capability of two supply lines, and these tips furnish substantial punch for most conditions. Some cities or towns may, because of hazards or flow capabilities, justify larger tips for initial use.
   b. Self-adjusting, variable flow nozzles may help solve the hydraulic problem in areas where supplies are questionable.

7. To gain maximum effectiveness, the angle of streams must be appropriate to achieve proper distribution and application. The angle of application will determine the amount of fire the stream is hitting. Where the ceiling above is still intact, the stream should be directed at the ceiling, entering just above the sill, allowing deflection downward for break-up and proper application. In the case of wide pattern spray nozzles, the appliance will have to be closely placed for proper coverage.

Using straight streams, if the appliance is placed close to the building, its effectiveness is limited to the lower floors.

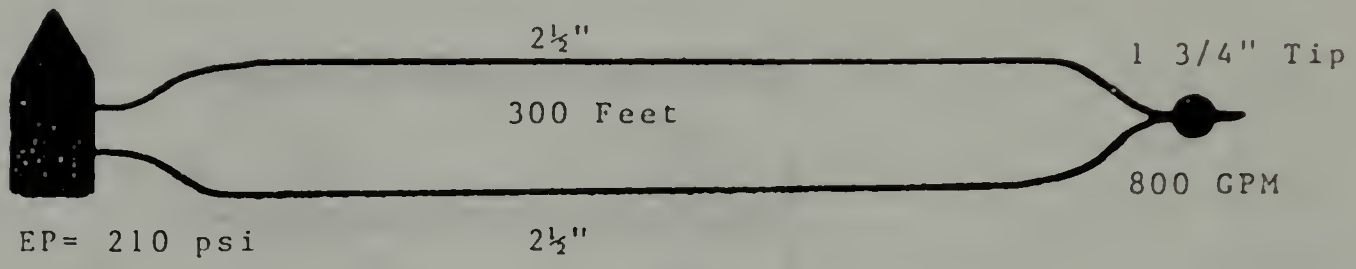


As the appliance is moved farther away from the building, its effectiveness increases on upper floors. Generally speaking, deck guns are not effective above the third floor.

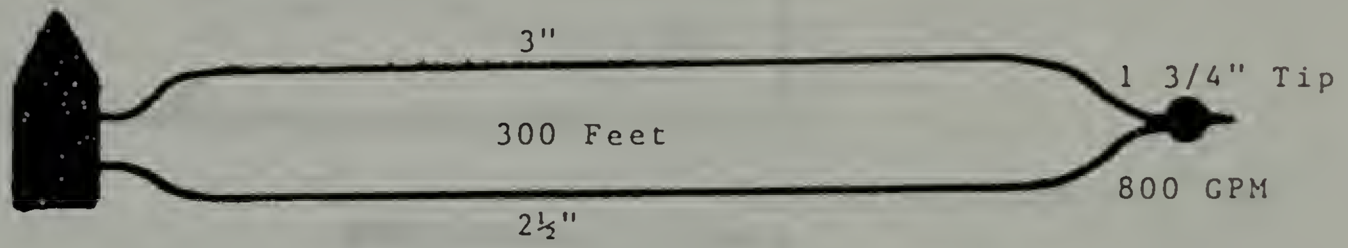


8. Master streams have a definite place on the scene of hazardous material incidents.
   a. For applying large volumes of water to cool exposed tanks or other storage facilities.
   b. To provide reach, keeping personnel a safe distance from potentially dangerous materials.
   c. For providing unmanned positions for water application.

9. Although it is not the intent of this text to involve itself with technical fireground hydraulics, there must be mention here of the planning, selecting, and use of hose lines to supply appliances. The illustrations below are drawn to show the varying effectiveness of 2½" and 3" hose for supplying appliances. Many fire departments are using a split hose body, packing one side with 2½" and the other with 3" or larger.

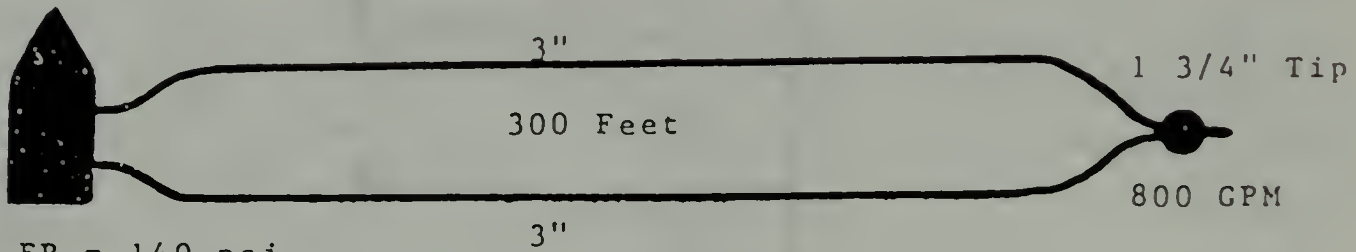


EP= 210 psi



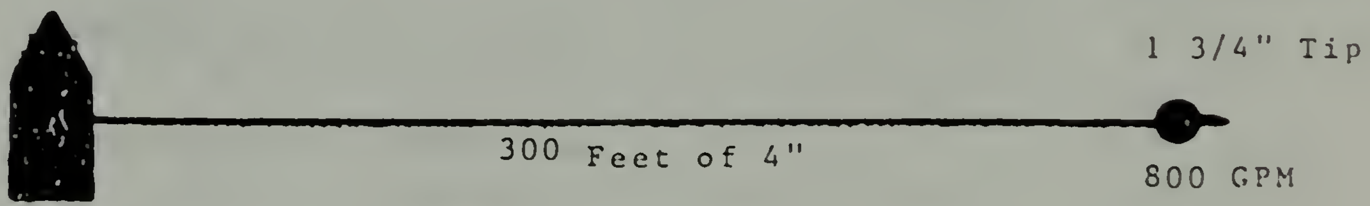
EP = 165 psi

The use of two 3" lines would, with the same layout, reduce the EP another 25 psi, to 140 psi.



EP = 140 psi

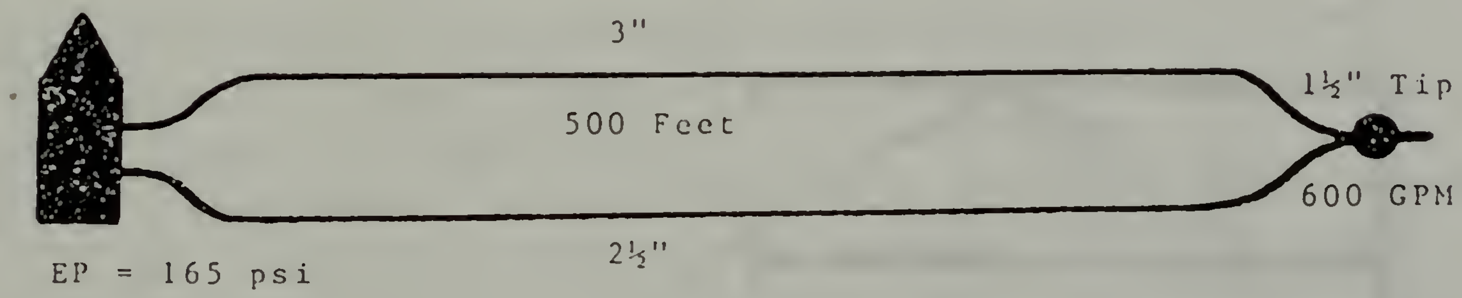
(Under average fireground conditions, using 2½" or 3" hose, do not attempt to supply a master stream with <u>one</u> supply line.)
And the use of large diameter hose would reduce the EP to 126 psi



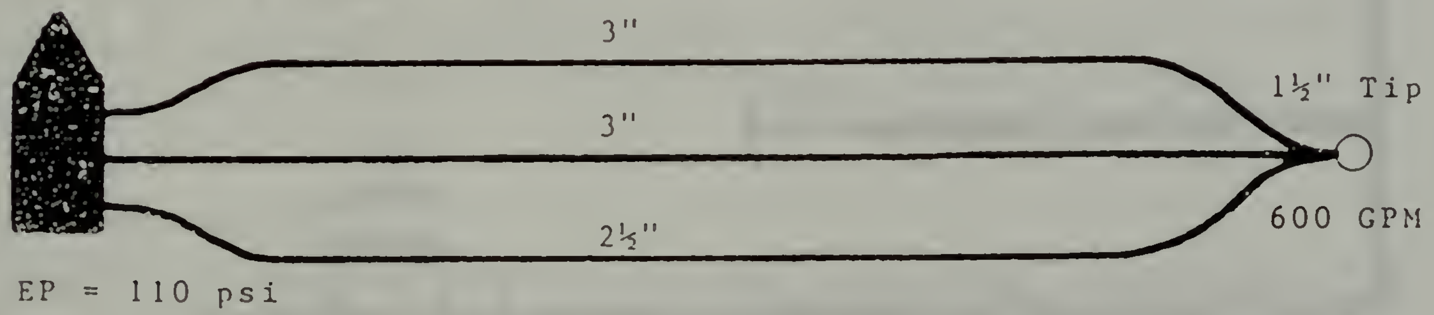
EP = 126 psi

NOTE: There is a reduction in EP as the size of supply lines is increased.

Another point that should be remembered is the advantage of adding a third line to appliances. If only two lines are used for supply, each may be carrying close to its effective capacity, resulting in high friction loss and engine pressure.



Adding a third line to the layout, either during initial operation, or later, will allow the EP to be reduced.

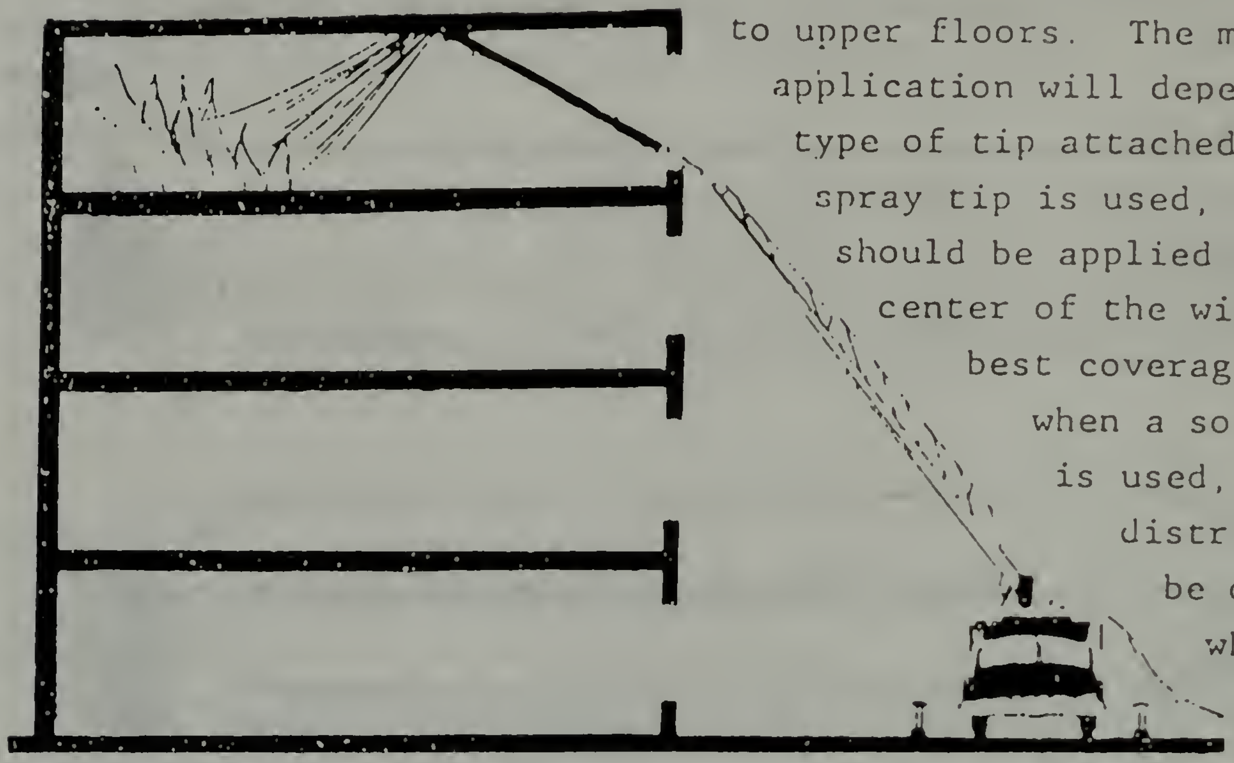


10. Putting master streams into operation requires manpower - a luxury many departments do not enjoy, especially during the early stages of a fire when large calibre streams are sometimes needed the most. Those departments that have serious manning problems should look closely at the advantages of pre-connecting appliances to the pump for quick operation; also to the use of large diameter hose, in order that companies can be more self-supporting.

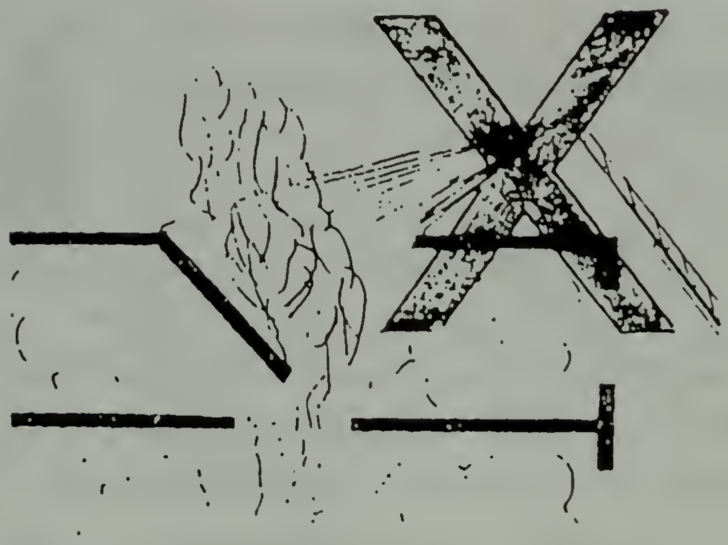
    During those evolutions of putting appliances into operation, manning is essential, and personnel not engaged in other support activities are usually assigned to the task of setting the appliances. Once in operation, however, officers should consider the re-assignment of personnel. It is not uncommon to find four or five firefighters on the turntable, or holding down a gun, when they could be more effectively used somewhere else on the fireground.

11. Avoid the promiscuous directing of stream into smoke. If the stream is not hitting fire, shut it down and use the water somewhere else more effectively. When conditions permit, as the bulk of fire is knocked down, reduce down to the more mobile hand lines.

12. Place the stream at a vantage point that will extinguish the fire and not cause extension of fire by improper application.
13. The use of ladder pipes provide, if properly used, rapid and efficient application of water to upper floors. The method of application will depend on the type of tip attached. If a spray tip is used, the tip should be applied in the center of the window for best coverage. However, when a solid stream is used, the best distribution can be obtained when the stream is deflected off the ceiling. In order to obtain such deflection, the placement of the tip should be at approximately window sill level, directed upward as shown.



14. As discussed in the Ventilation section, directing ladder pipes down through openings in the roof, in most cases, will defeat the natural path of travel, and push heat and fire back down into the building.



SALVAGE

The cooler the flame gets the less dramatic the fireground operation appear. Certainly, salvage falls into the category of less dramatic. However, it is probably an area in which much dollar loss can be prevented. Insurance companies formed salvage companies in the late 19th century to reduce water damage caused by the introduction of the steam engine into the fire service. Their attempt was to minimize water damage and reduce losses. Since the disbanding of such private companies, most fire departments have recognized this responsibility as a part of their usual fireground operations. Requirements for the equipping of ladder trucks, as set forth in Pamphlet #1901, include salvage covers, mops, squeegees, water vacuum, and other such equipment that will aid in not only reducing unnecessary damage, but allow the homeowner or businessman to use his building sooner than might otherwise be the case.

PRE-FIRE EFFORT

Effective salvage operations can and should begin before the incident. During in-service inspections, the company officer can give advice to the property owner or occupant that may result in a saving to property in the event of fire. As an example, occupants should be advised:

1. All smoke and fire doors must be properly maintained and in proper position to eliminate the unnecessary extension of fire or products thereof.
2. Storing of stock should be on pallets that keep such stock off the floor.
3. Records, vital to the operation of a business, must be stored in a manner that will provide retrieval and use after a fire.
4. Proper maintenance must be established for fire protection systems.
    a. Distances between sprinkler heads and piling of stock must provide adequate clearance for the effective distribution of water from such heads.
    b. Aisles must be maintained to provide rapid access to valves.
    c. Spare sprinkler heads and appropriate wrench should be provided.
5. Proper clearances must be provided between piles of stock to

reduce rapid propogation of fire.

6. A proper fire detection system, if not installed, should be recommended as a property saving device and form of salvage
7. Features of construction that may assist firefighter's efforts during salvage operations, such as floor drains, should be marked and maintained.

TRAINING

Good salvage operations, like other factors on the fireground, begin with training. The common sense practice of trying a door or window before putting an ax through it must be brought to the attention of the firefighter during drills. The old adage " Try before you pry" thereby becomes an automatic reflex on the fireground. There are many steps that can be taken by members during their operations that take little time, but when implemented, can contribute to property conservation. Simply removing the curtains, drapes, or other loose materials before setting a smoke ejector may eliminate the loss of such expensive items to the pull of the ejector, and due to the negligence of the fire department. Consideration for the property owner will encourage implementing such safeguards as spreading of runners over valuable rugs or stair coverings, providing protection for such items against the dirty, wet boots of firefighters.

It is only through training that nozzlemen recognize that proper direction and shutting down of the nozzle will prevent unnecessary water damage. The promiscuous directing of streams into smoke, and the lengthy, untimely discharge of water beyond the time of fire knockdown, contributes substantially to increased water damage and can only be reduced or eliminated by trained, aware firefighters. Such training will not only reduce water damage, but probably save much valuable time later on conventional salvage methods.

OPERATIONS

The most typical method of salvage is the covering of contents with salvage covers and the removal of water.

Salvage Covers. Salvage covers should be stored in a folded form that will best enhance their quick but uncomplicated use. Through experience and use a fire department will determine whether a one-man, two-man, balloon throw, or other spreading procedure can best be accomplished with available resources, and will fold their covers accordingly,

The spreading of salvage covers generally involves first the appropriate arrangement of materials to be covered. Such arrangement should be accomplished in a manner that offers protection to fragile items. Consideration must therefore be given to such items as mirrors, pictures, glass items and valuables that may be found on dressers or bureaus. Such items may be placed in drawers or place in a manner that allows for their protection by stronger articles, then covered with the appropriate size salvage cover.

Although the usual use of covers will involve the arrangement of contents and spreading of covers, there will be times when conditions will require the improvising of the use of covers to protect contents that cannot be conveniently arranged. Such practices may be necessary in stores where wall shelves must be protected. Under such conditions improvising and ingenuity will be a determining factor in the amount of salvage that can be accomplished. It must be reemphasized that the extent of salvage that a department is able to accomplish will be proportional to the training its members have received in the methods of carrying outs such evolutions.

Removal of Water.The accumulation of large amount of water can create a very serious situation and must receive its due attention by the OIC, particularly where such water has accumulated on upper floors.

Generally, removal of water should begin on the lowest level, working upward to avoid overloading of floors. The water will have a natural tendency to collect at the lowest level, thereby creating the possibility of considerable damage to machinery, utilities, or other services within the building. Attention should be directed early into salvage operations to the opening of floor drains if available, or other means of ridding the basement of water. Through the proper use of salvage covers, or through other available means, water may be routed out of the building at upper levels, or channelled via stairs or other shafts, safely to the outside.

OVERHAUL

Once all visible flame has been knocked down, attention must be directed to opening up and investigating the building's contents and concealed space that were directly effected by flame or heat. It is this orderly examination called OVERHAUL that is designed to discover and extinguish any smoldering or hidden fire that could otherwise cause a rekindle.

FIREFIGHTER SAFETY

Since firefighters who were involved in initial attack operations are apt to be fatiqued at this stage of operations, officers should be particularly concerned about safety. Whenever extensive overhoul is undertaken after a lengthy struggle for fire control, fresh crews should, if possible, be detailed for the remaining operations. If manning levels prevent the relief of attack crews by fresh crews, officers should give consideration to a rest for the most exhausted before resuming duties.

Full protective clothing will be necessary. Since eye, hand, and foot injuries are among the predominant injuries incurred during overhaul, faceshields (in place), gloves, and inner soles will be particularly helpful to reducing injuries.

During overhaul, visibility is usually so improved over that during fire conditions that there is little evidence to firefighters of irritants that may cause discomfort or respiratory problems. It is at this stage of operations that firefighters welcome the opportunity to relieve themselves of the burdensome weight of their mask

and tank. Recent studies have indicated the danger of such action. Products of combustion from PVC, PCB, cellulose, and so many other materials commonly found in structures today, linger in the atmosphere for long periods beyond fire knockdown. Even carbon monoxide may be at highly concentrated levels for extended periods into overhaul, particularly in upper levels of the structure. Breathing apparatus, therefore, may be required for considerable time into the overhaul process. Officers should be alert to the amount of ventilation that has been accomplished, and its duration, as well as the need for additional power venting to rid the atmosphere of contaminants. Only with this awareness can officers and firefighter properly evaluate when breathing apparatus should be removed.

One of the prerequisites before starting a search for hidden fire is to determine the condition of the building. An inspection of the premises should be made by fire personnel before allowing men to begin overhaul. Such an inspection should include:

A. Satisfaction of structural stability of the building, particularly those areas where crews will be working. The degree and intensity which the fire attained during burning will indicate the extent to which the structure has been weakened. A 1972 hotel fire in Boston pointed out to us all that building alterations sometimes go unannounced to authorities, and can seriously effect the structural integrity of a building. Any areas that may be a threat to the safety of personnel should be so marked and roped off.

B. Consideration must be paid to the amount and distribution of weight on floors.

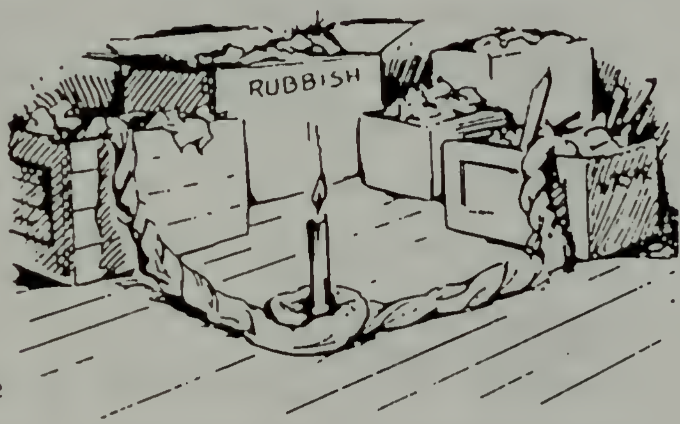
   1. The amount of water used during fire control operations may have considerable influence on the safety of structural members. Water itself, at considerable weight (8.33 lbs/gal) may accumulate on floors at depths that constitute a weight hazard. A stream of water, discharging 250 GPM, and directed into a building, will add a ton of additional weight per minute.
   2. The absorbant qualities of contents may unsuspectingly increase the load placed on floors. Stuffed furniture, cardboard, and particularly baled goods, are examples of contents that may absorb great amounts of water.
   3. Crews should be reminded that floors are strongest nearest the walls, and overcrowding or storing of excessive

contents near the center of floors should be avoided. Pooling or a puddle of water in the center of a floor may be an early indication of weakening

During night fires, the work area must be adequately lighted. Fire may have burned through floors, roof, stairs, or other areas that may create considerable hazard to the work of firefighters during overhaul. Illumination should be a priority to improve safety as well as aid in identifying areas to be opened up.

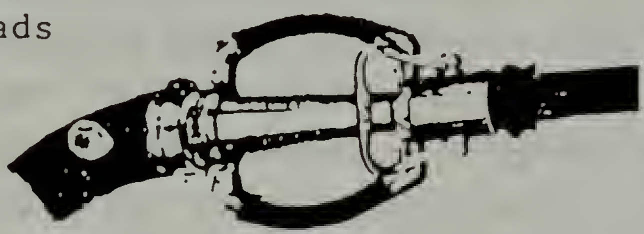
PRESERVATION OF EVIDENCE

Once the fire is knocked down, a process must begin that allows someone in authority to read the fire language in order to determine what actually happened to cause the fire. The reading of evidence involves surveying the building and contents to determine the point of origin, path of travel, cause and source of ignition, evidence that points to arson, and the preservation of any evidence found. Fire personnel at all levels must be trained in the identification and preservation of evidence. It is commendable for fire departments to restore the premises to some neat and liveable condition for the owner. However, many an arson investigator has been frustrated on arrival at the fire scene only to find all possible evidence buried amid a pile of debris on the front lawn or sidewalk. Investigation of the cause and circumstances surrounding the fire, and overhaul, generally begin at about the same time. Overhaul must be thorough, to uncover hidden fire. It must also be done with an awareness that lying in the building or contents are signs that, if disrupted, may eliminate positive determination of the cause. Any materials suspected ob being evidence must not be disturbed during overhaul until seen by the authorized investigator.



PREPARING FOR OVERHAUL

Usually, less water is needed for overhaul than during fire control operations. Therefore, as soon as conditions permit, 2½" lines should be reduced down to 1½" lines for mobility, ease of handling, and reduction of water damage. 1½" threads are usually provided on 2½" nozzles to accomodate such quick conversion to the smaller lines. Also, at this stage



of the fire, lines may, in accordance with the judgment of the OIC, be disconnected from apparatus, and run directly off a hydrant (providing sufficient hydrant pressure is available.) This change-over will release apparatus for eventual return to quarters, or remain on the scene "in-service", depending on the condition of equipment and appliances carried thereon. Such action will also open, at least partially, streets to traffic flow.

If not already done, the owner and/or occupant(s) of the building should be contacted. Once on the scene where extensive overhaul operations are necessary, such persons may provide assistance through equipment (forklifts, loaders, etc.) or advice and assistance to unfamiliar or barricaded areas. The heating unit should be checked to make sure it is on in order to dry out the building and contents. The owner may also take other reasonable action he or she feels necessary to protect their belongings.

WHERE TO BEGIN

Making the building and area safe means prevention of additional problems that may cause injury or property loss. The word "safe" applies to the protection of personnel and public against rekindle, explosion, falling objects, or other possible occurences that may result from a neglected fire scene. To carry out this objective, officers and firefighters must consider the building, its contents, and the area involved. The order in which they should be considered will depend upon a survey of conditions.

A primary objective in searching for hidden fire should be to make a systematic and careful check to determine whether the fire extended to other areas. Examination should be made of common spaces in which fire may be concealed, such as walls, partitions, attics, cocklofts, ceilings, floors, and shafts. Determination of where areas are to be opened will be through the senses of Look, Listen, Feel, Smell, together with experience.

Look: Discoloration at baseboards, door and window casings, or other areas where hidden fire or trapped heat may seek venting to the atmosphere.

Listen: The crackling of fire within concealed spaces may provide an obvious indication that such areas must be opened up

Feel: Where suspicion exists as to the extension into concealed spaces, remove gloves and feel for excessive heat. Although walls and ceilings will undoubtedly show evidence of residual heat from fire conditions, excessive heat will indicate areas that should be opened for further observation.

Smell: Especially in cold weather, steam will be generated from the immediate fire area for long periods of time, and is often difficult to distinguish from smoke. The sense of smell, together with observation of any color difference or build-up, will serve as indicators of hidden fire.

Experience: Through the knowledge gained at past fires, as well as knowledge of building construction, an officer can acquire a "feel" for where additional spaces must be opened, and when he is comfortable with the condition of the building.

When concealed spaces below floors, above ceilings, or within walls and partitions are to be opened for search of hidden fire, the furnishings or other contents should be moved to a safe location, and covered to prevent further damage.

In multi-story buildings, all floors of the building must be examined after a serious fire, particularly the top floor. Then, overhaul should begin at the highest floor effected by fire. A section of the floor near the wall should be cleared for the placement of overhauled materials, making sure there is no fire behind this wall. Where suspicion exists that fire is in a wall or ceiling, such space must be opened up to a point where the officer can see signs of unburned construction materials.

NOTE: It is easier answering to why a space was opened up and no fire found, than why not opening up resulted in rekindle.

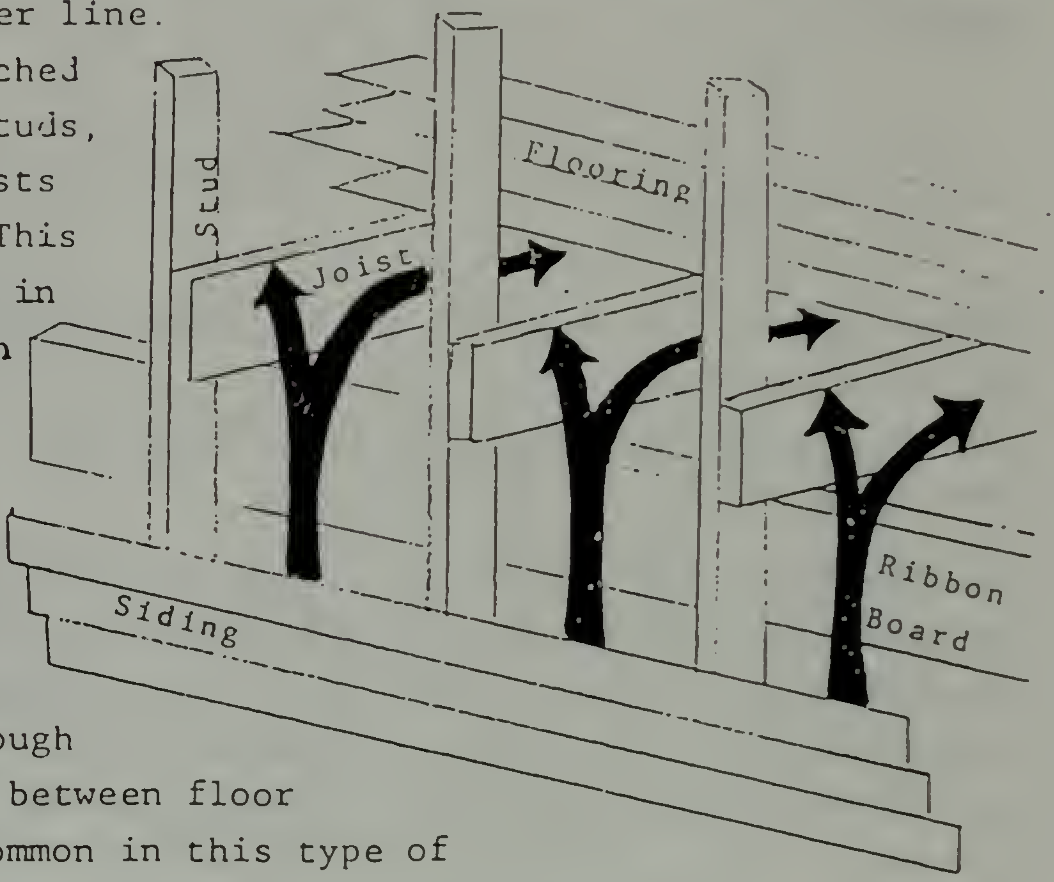
The opening will often have to be of ample size to get a handlight in to look the entire length of the wall or ceiling bay.

PROBLEM AREAS

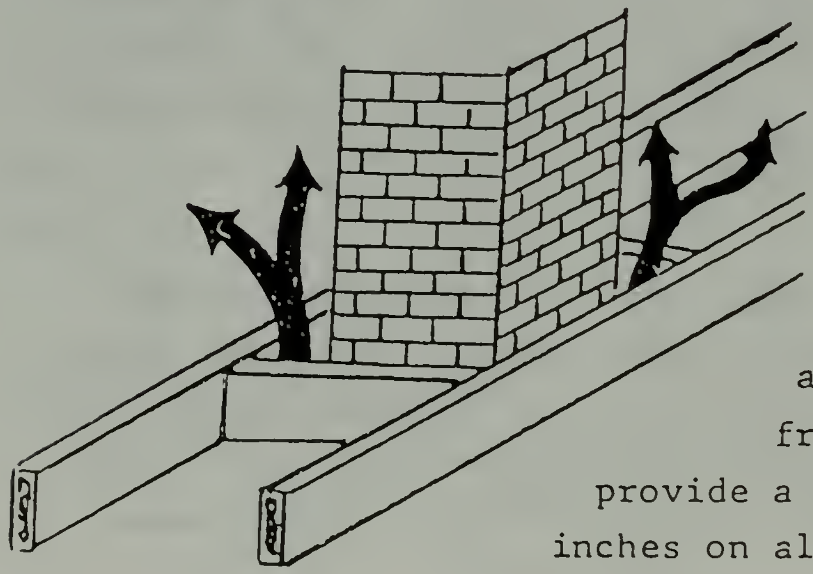
"Concealed spaces" is a term that describes a multitude of voids that exist within buildings, sometimes causing major problems during both firefighting and overhaul operations. Just as such spaces may contribute to the undetected spread of fire before discovery, they may prevent the detection of open or smoldering fire unless opened and exposed. It will be difficult, if not impossible, to cover in

this manual, all the examples of concealed spaces. There are, however, two popular types of construction, each of which contains many of the common voids that must be addressed by men and officers during overhaul. They are the Balloon frame dwelling and the Taxpayer mercantile building.

Balloon Frame Dwelling. The Balloon frame dwelling comes in assorted models; 1½ story, 2½ story, three decker, as well as others. Balloon construction is that type of early construction associated with non-firestopped walls. Studs in this type of construction run from the foundation to the gutter line.

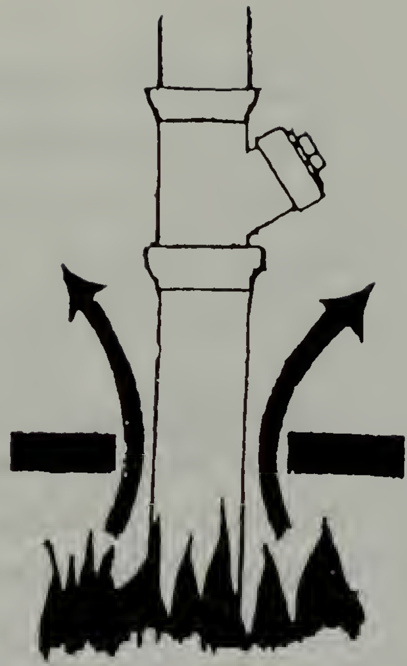


A ribbon board is attached to the inside of the studs, on which the floor joists are set and secured. This construction, as shown in the accompanying sketch presents a non-fire-stopped open void from cellar to roof, providing a channel in which fire can travel unretarded, and often undetected, upward through walls and horizontally between floor joists. It is not uncommon in this type of construction to have fire travelling up an outside wall, across the attic, and via convection currents, down an opposite wall or interior walls.



There are other channels, common to this type of construction that also not only allow, but invite through upward draft, the unrestricted upward travel of fire. One such avenue is the chimney breast. The framework around the chimney may provide a space of from ½ inch to 3 or more inches on all four sides of the chimney, from cellar to roof. Standing in the attic, it may be

possible to drop a small stone down the chimney breast, and a moment later hear it hit the cellar floor.

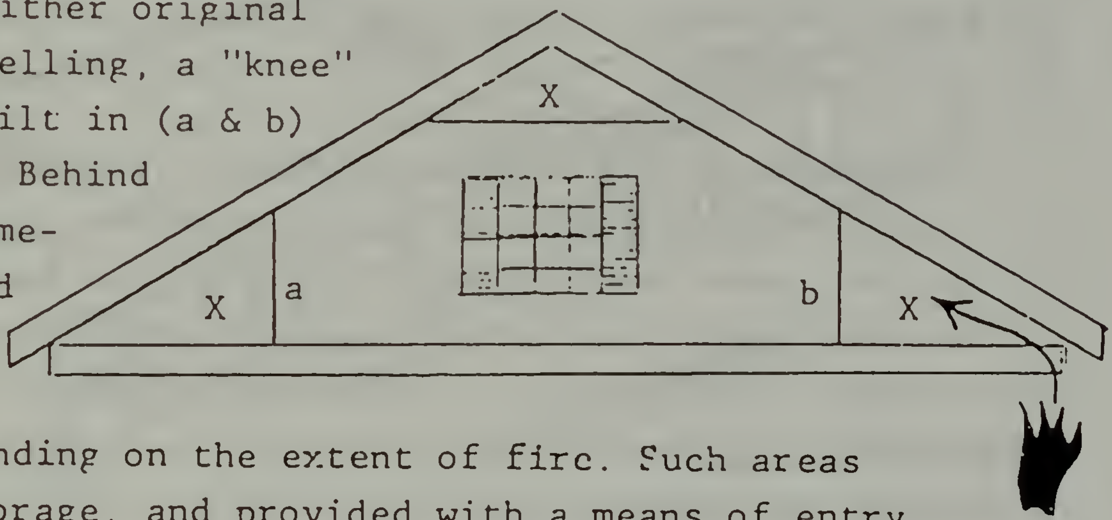


Another thoroughfare that may contribute to a cellar fire becoming an attic fire in this type of construction is the pipe chase. The pipe chase is like the chimney breast in that the area around a soil, water, or heating pipe, as such pipe passes upward from floor to floor, invites the rapid upward and horizontal spread of fire.

These types of concealed spaces not only conceal fire, but contribute to the rapid movement of fire both vertically and horizontally, and make an advancing fire in this construction a nightmare unless discovered and extinguished quickly.

During overhaul, these areas must be check quickly. If it is suspected that fire may be found in one or more of these areas, it will be necessary to check upper levels and/or open up around the concealed space to search for evidence of extension.

A prime example of a concealed space is often found in the attic as diagrammed. During either original construction or remodelling, a "knee" wall may have been built in (a & b) to finish the attic. Behind the knee wall, and sometimes overhead, marked "X", are concealed spaces that may require opening, depending on the extent of fire. Such areas are often used for storage, and provided with a means of entry.



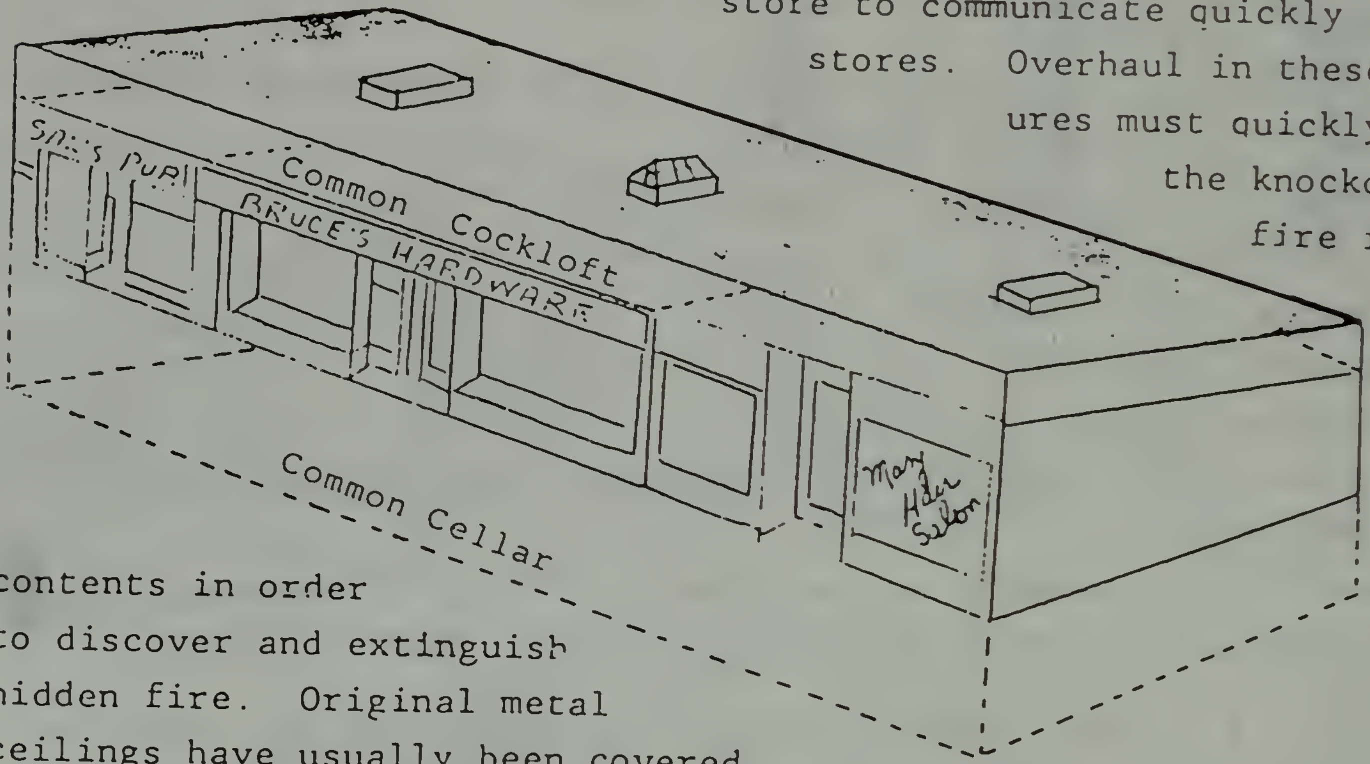
Construction features that were popular during the era when balloon frame structures were being erected also contained other concealed spaces such as behind china closets, sliding doors built into walls, dumbwaiters, and others.

Problems that existed in balloon construction led to development of a "closed" or firestopped construction found today. Concealed spaces, although still in existence, are more apt to be limited in area.

However, it is not uncommon today to find that tradesmen have rendered firestopping inadequate by not effectively closing floor openings (or horizontal openings through walls) made to accommodate ducts, pipes, wires, etc. During overhaul, attention must be paid to possible extension, regardless of the class of construction.

The Taxpayer. The Taxpayer can also be used as an example of construction the has common concealed spaces that must receive attention during overhaul. The Taxpayer is a name given to those one story mercantile stores, constructed quickly and cheaply during the Depression era by the land owner to pay taxes on the land. The building was erected with balloon frame construction, and most often with a common cockloft and common cellar. The cellar is usually divided off with chicken wire or other flimsy barrier that does not retard f--re horizontal fire spread.

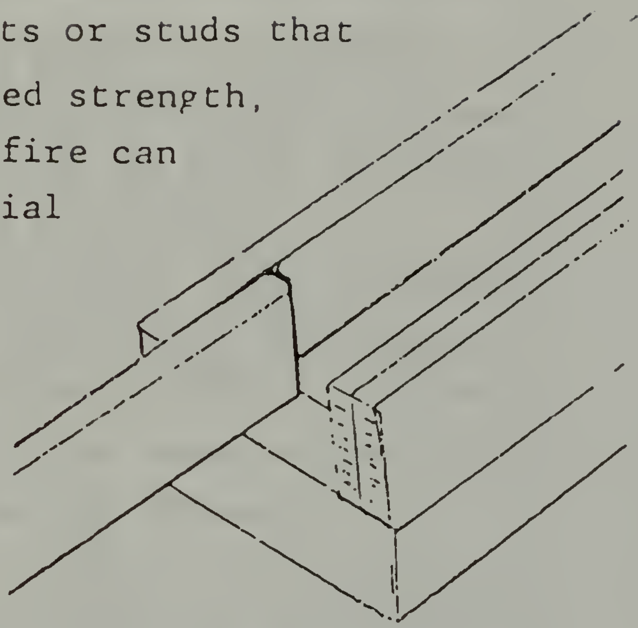
The balloon frame construction, together with the type of cockloft and cellar, provide excellent opportunity for fire in area or one store to communicate quickly to other stores. Overhaul in these structures must quickly follow the knockdown of fire in room . and contents in order to discover and extinguish hidden fire. Original metal ceilings have usually been covered over the the years by a more modern dropped ceiling, presenting another concealed space. Fires in these buildings may make it necessary to pull ceilings as far away as two or more stores from the store of origin in order to check for overhead horizontal extension.



MISCELLANEOUS TROUBLE SPOTS

Concealed spaces can be a serious problem during all aspect of overhaul. There are, however, other areas that, through experience

become known as routine trouble spots that must receive special attention when found. For example, joists or studs that overlap, or have been doubled up for added strength, provide that minute space between where fire can hide and smolder for hours. If substantial charring has taken place, such joists or studs may have to be separated and wet down thoroughly.



The same type of hidden fire can present itself in double floors. Remodelling work may have added another layer of flooring, sometimes more than two, that will have to be overhauled to check for evidence of hot spots.

As previously discussed, when fire has burned around windows or doors, there is a possibility that there is fire remaining within the casing. Under such conditions, removal of facing will be necessary. Another trouble spot in this area is the window rope, capable of smoldering for hours.

A smoldering mattress, chair, or sofa, can become a particular problem when removing it to the outside for final overhaul and extinguishment. A most dangerous and embarrassing scene can develop when the piece of furniture comes in contact with the open air and bursts into flame at the doorway. The situation can become compounded if the article gets jammed in the doorway as flames erupt. When it becomes necessary to remove a piece of furniture touched by fire to the outside, it must be accompanied by a charged line.

Before leaving the scene of the fire, the OIC should again make a thorough examination of the entire building, and of any adjoining property to which fire could have extended, or which may have been affected by the fire.

After overhauling operation have been completed, it may be necessary to leave a detail of men at the scene for several hours to guard against the rekindle of fire. Such a detail should be equipped with the proper tools and appliances in order that they can effect-

ively perform their assigned tasks.

It should also be noted at this point that most fire departments have a policy of maintaining a charged line on the property of suspicious fires for the purpose of retaining control of the building. It is during this overhaul period that the fire department retains control of the fire building and allows the uncontested investigation of the fire to determine its cause. Once the fire department releases control of the building back to the owner, it oftentimes becomes very difficult for the fire department to re-enter the property for further investigation.[1]

It may also be necessary to notify the proper utility companies in order that the building be placed in a secure condition.

[1] Tyler vs Michigan has recently established some guidelines for defining "reasonable" time that the fire department can keep control of the building after extinguishment.

FIRE SCENE TERMINATION

As the salvage and overhaul phases of operation are in progress, the OIC should give consideration to those tasks and responsibilities that accompany the termination phases of the overall incident. Department procedures and policies will necessarily differ from one to another regarding the fire department's overall obligation to the incident scene, but the following guidelines regarding incident termination will assist the OIC in securing the scene.

One of the most important tasks is to contact the owner or his representative to inform the owner of the incident involving his property. Assistance in this task may be secured from the local police department, or records of ownership on file at the local assessor's office.

Securing the building against trespassers and the elements of weather where the fire fire department has made entry or ventilation holes will not only enhance public relations between the fire department and the citizens it serves, but may also prevent repeat responses to the same scene. This phase of fire scene termination involves covering broken windows, closing windows that are not broken, covering ventilation holes in the roof, and in freezing weather, advising or assisting the owner in draining the sprinkler system and plumbing system in those cases where the building cannot be heated.

Where a minor fire has involved the operation of the sprinkler system and several heads have fused, sprinkler protection can be restored by replacing those fused heads and restoring the water supply to the system in the presence of the owner or his representative.

If utilities such as gas, electricity, or water have been shut off by the fire department, those affected utilities must be notified so that no future legal responsibilities will effect the local fire department.

The OIC must make an effort to leave the property in a generally safe condition and place or cause to be placed, safeguards at any dangerous areas. If the fire department caused water to flow on the sidewalk(s) and into the street during freezing weather and

icy conditions result, notify the Public Works Department to sand the area. If the fire department piled debris on a public way, notify the proper agency to remove the debris or secure the area.

When necessary, request the police department to maintain surveillance of the property to guard against looting, vandalism, or any unauthorized entry.

Where occupants of a building cannot reenter the structure to resume habitation, request the assistance of an agency such as the Red Cross to provide shelter or needed clothing. Oftentimes the victim's homeowner policy will provide for hotel or motel accommodations. If this is not the case, a service organization such as the Red Cross should be notified.

An investigation for the cause of the incident must be made prior to securing from the scene, as described in Chapter 148, Section 2 of the General Laws, which may include causes such as accidental, suspicious, arson, undetermined, etc.

While investigating, companies must be instructed to do overhauling and salvage work carefully, using care in the operation of hose streams. When evidence is found, it should be moved only if absolutely necessary, handled as little as possible, photographed, properly guarded and/or barricaded. Records must be made of the time, date, location and circumstances under which the evidence was found. If necessary, specialized personnel involved in the investigation of fires must be summoned to the scene.

Companies operating at the scene need to be relieved and placed back into service as the incident terminates. One or more companies may have to be held or assigned as a fire detail to ensure no rekindle of the fire, or to assist the investigator by maintaining a hose line in the building, thereby maintaining control of the premises.

Finally, the OIC must compile the needed reports of the incident, including those for the State Fire Marshal and/or the local department. The report of the incident should include what the fire department found on its arrival; how the situation was handled; describe what damage was done by the fire department; and detailed enough to indicate the condition of the building and who

was left with control of the building when the fire department left the scene. Reports of the overall incident management should be adequate enough to detail the operations, in the event the incident is involved in future legal proceedings. It is not uncommon for the OIC to receive a summons to court on a matter that occurred two, three, or more years ago. Documentation must be available to that OIC to substantiate his testimony.

Appendix

Module 2: Quick Fire Flow Calculations

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Objectives

* The student will be able to explain the rationale behind the quick calculation method.

* The student will calculate needed fire flow for given scenarios using the quick calculation method.

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It is important for the purpose of fireground resource management that determination be made on the requirements for water needs. Many professional fire officers today recognize the need for a standardized system for determining water requirements. It is recognized, however, that there is not time for complex computations at a fast moving fire.

In the light of the problems confronting the fireground officer, a system for quick calculations should be utilized.

CUBIC FOOT FORMULA

Some of us are familiar with the cubic foot formula: length x width x height divided by 100. The formula has been validated through years of use. It roughly parallels the Insurance Services Office's (New York, NY) estimates based on the fact that a gallon of water will inert a 200 cubic-foot space when converted to steam. However, let's be realistic about such formulas. Actually, they are a starting point from which an officer makes an estimate for water required.

The basic cubic foot formula is in many ways a physical or engineering issue. There are several people who have done studies involving the formula. The most notable of these are Keith Royer from Iowa State University, Warren Kimble and Lloyd Layman, authors of books on water supply for fire protection. All of the above persons start with the basic position that a gallon of water when converted to steam will inert or cool about 200 cubic feet of space in an enclosed area. K. Royer found that it will occur in about 30 seconds.

BASIS IS RATE OF HEAT ABSORPTION

Since the formula is based on the heat absorption rate of water, the majority of those engaged in the theoretical discussion feel that additional water need not be introduced into the building and little or no additional water should be needed for

exposures. In effect, the fire will go out, thereby reducing or eliminating the exposure problem.

Both the foregoing are based on the fact that the building is intact, reasonably tightly sealed and the water is introduced at maximum required flow. In that instance, that fact appears to be correct both from an engineering standpoint and in actual tests.

For the purpose of fireground management, the cubic foot formula is a tool to enhance one's management capability. It is not a panacea, however. It is a starting point in one's analysis of resource and deployment requirements.

Once the water requirements are determined, then and only then, can the incident commander determine how much personnel will be needed at the scene of the fire. Remember, fire equates to water and water equates to personnel. Fire engines do not put out fires; firefighters do!

FORMULA IS STARTING POINT

The cubic foot formula is a starting point. If the building is vented or explosions are occurring, or the contents are hazardous, or the wind is fierce, then obviously the requirements for water deployment change. Water delivery will also change. It is often carried off in convection currents. Many times the water will not reach the seat of the fire. If this is the case, additional lines may be needed. The intensity of the fire in an open building will make a difference. In actual practice the more intense the fire, the greater the need for larger streams.

Exposures are another consideration. As pointed out earlier, additional water may not be needed for exposures beyond that which is indicated by the cubic foot formula. However, if the fire is of such a magnitude that it is threatening exposures, then water must be deployed on the exposed surface. The main reason for additional percentages of the original amount being added for exposures is to identify the water, hence, the personel, required.

FIELD FORMULA

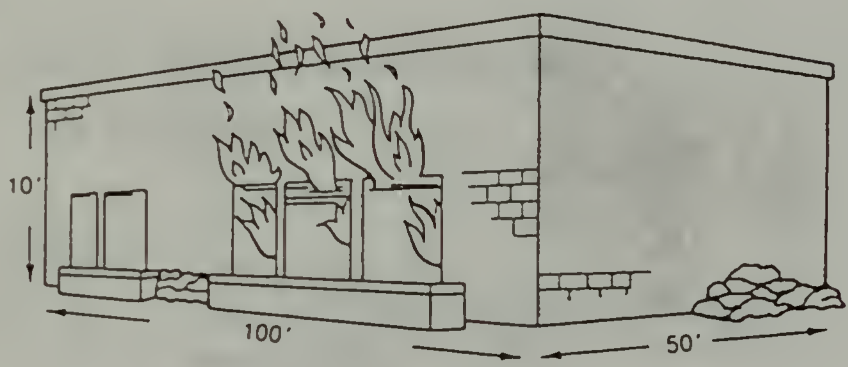
Since the quick calculation method is a field formula, it has been kept simple. In doing so, some of percentages are variable and far from absolute. But, in effect, this does not have a great impact on the overall fire, since as pointed out earlier, it is only a starting point. Certainly, the incident commander will modify the original estimate after measuring the effect of the water deployed.

Let's review the cubic foot formula. See the diagram on the next page. Note that the cubic feet figure is divided by 100

which is Royer's figure. His testing indicated knockdown in 30 seconds. Since knock-down occurred in one-half minute, one would also half the cubic foot divisor of 200 and get 100.

Cubic Foot Formula

$$\frac{\text{Cubic Footage of Fire Area } (L \times H \times W)}{100} = \text{GPM}$$



$$\frac{100 \times 50 \times 10}{100} = 500 \text{ GPM}$$

MODIFIED CUBIC FOOT FORMULA

Based upon the fact that it is an estimate, why not consider that all buildings are ten feet high? If the incident commander considers all buildings to be ten feet in height, then we can eliminate one step in the process. Likewise, by a rather simple mathematical gymnastic, the "length times the width" part can be shortened. The entire process is now down to a more manageable proportion. Here's how the same building is calculated using the modified formula.

1. Picture the length as a mathematical figure.

2. Take the zero(s) and set them aside.

3. Drop one zero.

4. Set aside the remaining zero.

5. Multiply the remaining whole numbers.

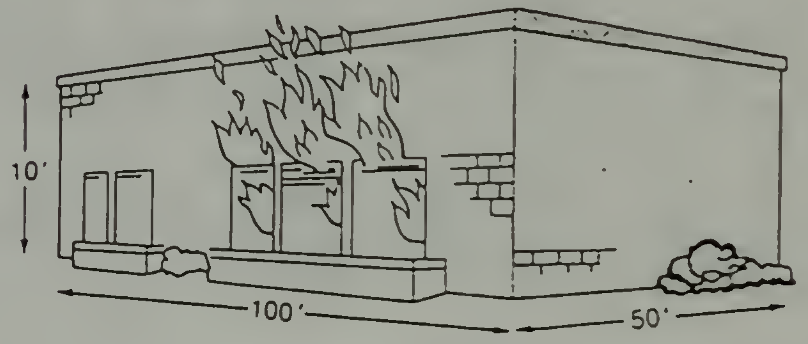
6. Add sequentially on to the product of Step 5 the remaining zero(s).

In the next figure note that only two zeros were held in mental imagery. They were added sequentially and the net figure is 500 gallons per minute, as in the original cubic foot formula.

Although the formula was worked using a ten-foot building, it will be close enough for an eight- or twelve-foot building. Remember that the purpose is to get an estimate for water needs. Other influences will change those figures.

Modified Cubic Foot Formula

Example #1



1. Estimate the Length and Width to the Nearest 10's or 100's	Length = 100 Width = 50
2. Set Aside the Zeroes, Drop One, and Remember How Many Are Left	000 → 00
3. Multiply the Whole Numbers Together	1 x 5 = 5
4. Put the Zeroes on Again	5 ← 00
	500 G.P.M.

SURCHARGE MODIFIERS

Two other factors must also come into play.

1. The percent of involvement;

2. The exposure factor.

Both of these can be combined into a single formula which can be expressed as follows:

Modified Cubic Foot Formula

Example #2: Gable Roof

1. Calculate G.P.M. for One Floor $\frac{40 \times 30 \times 10}{100} = 120$ G.P.M.

2. Gable Roof Attic Volume Is One-Half the First Floor $\frac{120 \text{ G.P.M.}}{2} = 60$ G.P.M.

Total = 120 GPM

NFF = base g.p.m. X % of involvement + exposure factor

The needed fire flow is computed by taking the base g.p.m. estimate determined by the cubic foot formula and multiplying this by the percentage of involvement of the subject building. To this is added a percentage of the base for exposure protection according to the Exposure Charge Table on the next page.

It should be noted that exposures whether interior (for additional floors) or exterior (adjoining, adjacent buildings or

materials) should receive a charge for each exposure and that each percent charge should be added together and then the sum becomes the multipier of the original base fire flow. Also the base fire flow is made on the fire floor. If it is a high rise there should not be a charge for floors below the fire floor. Accordingly, add for additional floors only if in your estimation the floor needs protection.

As to what constitutes an exposure, this is clearly a matter of judgement based upon experience.

Lastly, when computing for exposures, remember the formula is not an exact one. It must be tempered with judgement and experience. The formula, as a matter of fact, could include distance tables for exposures and all sorts of other applications until it would take a computer to solve for needed fire flow. Considering that a fire doubles in size in about a half minute, the incident commander does not have time to spend working out complex formulas.

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EXPOSURE CHARGE TABLE

<u>Exterior Exposures</u> (for exposed buildings)

1, 2 or 3 stories: 25% for all three floors

4 or more stories: 50% for all the floors

The charge is a total charge for the entire building and not a charge for each floor.

However, there is a charge for each exposed building.

<u>Interior Exposures</u> (for fire-resistive construction; steel and re-inforced concrete with no vertical openings)

For each floor above the fire floor: 25%

<u>Interior Exposures</u> (for older buildings; wood frame, wood and brick, etc. with vertical openings)

For each floor above the fire floor: 50%

==

EXAMPLES

Let's assume the building at hand is a two-story masonry office

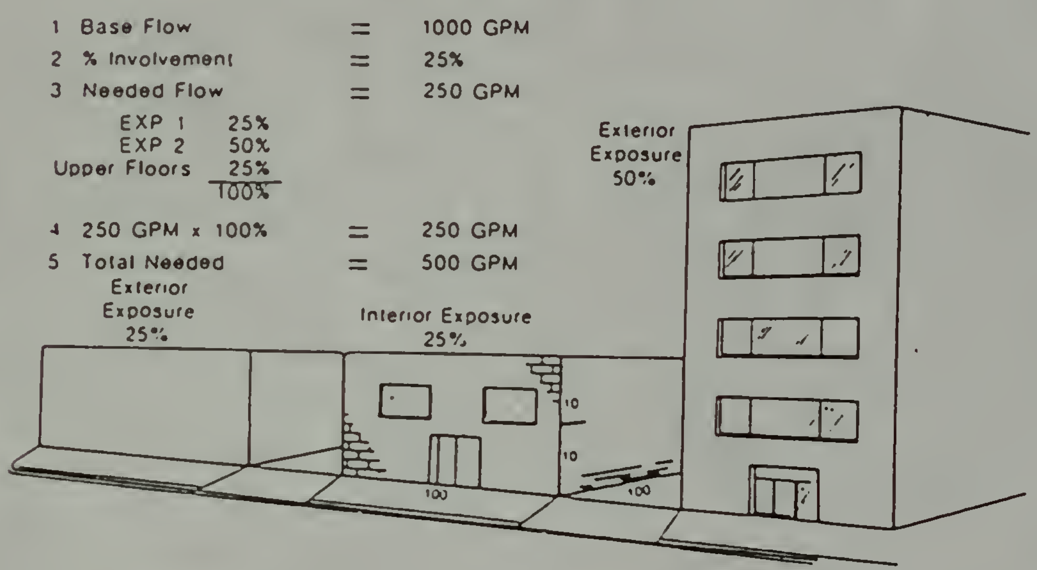
building with a base fire flow of 1000 g.p.m. The exposed edifice to the right is five stories high and the exposure to the left has two stories. The subject building is 25% involved. You begin by multiplying 1000 g.p.m. by 25% (involvement factor). This gives you a revised fire flow of 250 g.p.m. The exposure charges for this building are as follows:

1. Right exposure 50%
2. Left exposure 25%
3. Upper floors of subject building 25%

These amount to 100%. Therefore you take 100% of 250 g.p.m. and this gives another 250 g.p.m. The total needed fire flow will be 500 g.p.m.

Surcharge Modifier

Example Fire Resistive
Two Story Office Building



TWO CAUTIONS

A couple of cautions are in order. In computing the modified cubic foot formula, the basic g.p.m. is lower than the I.S.O. figure. The reason is that the I.S.O. computation is based on the fire <u>totally engulfing</u> the building which is lost. The cubic foot formula method assumes that the building is intact but involved to some degree. The formula offers smaller g.p.m. amounts than I.S.O. in some cases.

Most importantly, it must be pointed out that many other variables affect g.p.m. requirements. Whether the fireground commander utilizes the I.S.O. or a modified cubic foot formula, it must be remembered that the needed fire flow is only a starting point. Experience and subjective viewpoints must play a role in deployment and resource allocation as well as the ability of the firefighters to apply water in a timely and effective way.